AD-A128 604 THE DEVELOPMENT OF A DECISION AID FOR PASSIVE ACOUSTIC LOCALIZATION USING KNOWLEDGE OF THE ENVIRONMENT(U) NAVAL POSTGRADUATE SCHOOL MONTEREY CA G M VERMILLION MAR 83 1/1

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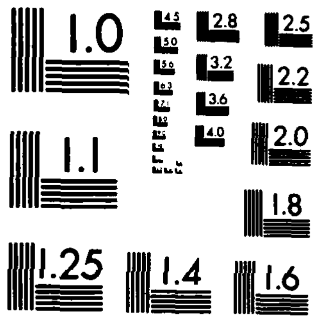

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Monterey, California

THESIS

THE DEVELOPMENT OF A DECISION AID FOR
PASSIVE ACOUSTIC LOCALIZATION USING
KNOWLEDGE OF THE ENVIRONMENT

by

George M. Vermillion

March 1983

Thesis Advisor: R. N. Forrest

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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A128604	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) The Development of a Decision Aid for Passive Acoustic Localization Using Knowledge of the Environment		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis March 1983
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) George M. Vermillion		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		12. REPORT DATE March 1983
		13. NUMBER OF PAGES 86
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Figure of Merit	Barrier
Propagation Loss Profile	Distributed Field
Sigma	Direct Path
Probability of Detection	Convergence Zone

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This thesis describes four microcomputer programs for evaluating sonobuoy effectiveness. The programs are based on the Gaussian signal excess model. The first program can be used to compare different sonobuoy employments, for example, a comparison between deep and shallow hydrophone depths. The second program gives a user the opportunity to display the effective extent of his pattern. The third program provides
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S/N 0102-LF-014-6601

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localization information using a buoy pattern and contact status. The program is based on a model that uses both positive and negative information from a field of sonobuoys to estimate target position; and is designed to give the operator an indication of where to deploy additional sonobuoys in order to convert single buoy to multiple buoy contact. Topographic mapping procedures are used to display the information in a graphical format that could prove useful to antisubmarine warfare aircrews.

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The Development of a Decision Aid for Passive Acoustic Localization Using Knowledge of the Environment

by

George M. Vermillion
Lieutenant, United States Navy
B.S., University of Utah, 1976

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN SYSTEMS TECHNOLOGY

from the

NAVAL POSTGRADUATE SCHOOL
March 1983

Author: George M. Vermillion

Approved by: ______________________ Thesis Advisor

______________________ Second Reader

______________________ Chairman, Antisubmarine Warfare Academic Group

______________________ Academic Dean

ABSTRACT

This thesis describes four microcomputer programs for evaluating sonobuoy effectiveness. The programs are based on the Gaussian signal excess model. The first program can be used to compare different sonobuoy employments, for example, a comparison between deep and shallow hydrophone depths. The second program gives a user the opportunity to display the effective extent of his pattern. The third program provides localization information using a buoy pattern and contact status. The program is based on a model that uses both positive and negative information from a field of sonobuoys to estimate target position; and is designed to give the operator an indication of where to deploy additional sonobuoys in order to convert single buoy to multiple buoy contact. Topographic mapping procedures are used to display the information in a graphical format that could prove useful to antisubmarine warfare aircrews.

TABLE OF CONTENTS

LIST OF FIGURES

I. BACKGROUND

The localization problem facing an antisubmarine warfare (ASW) air crew is very complex. The crew must properly employ a variety of acoustic and non-acoustic sensors and accurately process the resultant information to properly classify all targets and to identify, localize and prosecute the target of interest. The purpose of the research that is reported in this thesis is to develop techniques : analyze the effects that a changing environment can ve on this activity. The techniques that were develop are relevant to planning scnobuoy patterns for specific scenarios and they also lend themselves to use in localization algorithms.

In the prosecution of a submarine target, an air ASW crew will proceed through a succession of phases [Ref. 1]. The focus of this thesis will be the preflight, search and localization phases. The programs described in this thesis are designed to help the TACCO as well as Antisubmarine Warfare Operations Center (ASWOC) personnel make decisions regarding the selection of an initial search pattern. Additionally, a localization program is provided that could be used by the TACCO to expand a search pattern in order to convert from a single to multiple buoy contact.

The first two programs are designed to aid in pre-flight planning. They transform the output from an acoustic model, such as ASRAPS III, FACT or PL-Ray, to a probability of detection plot and a graphical representation of the effectiveness of the buoy pattern selected. The graph gives the operator an indication of how well the pattern he has selected will work for his particular scenario.

The remaining programs are used to aid the TACCO in the expansion of his pattern. The programs are designed to be used on an aircraft such as the P3-C (mod). Although there is currently no provision for on-board processing of this nature on current aircraft, the upgraded computer systems that are in development should allow the addition of similar software.

In general, the patterns employed will fall into three categories: barrier, distributed field, and convergence zone. The barrier pattern is designed primarily to gain direct path contact for a transiting submarine, while the distributed field and convergence zone pattern may be effective against either a transiting or on-station submarine.

In barrier tactics a straight (or curved) line of buoys is employed at a position that is determined to be ahead of the transiting submarine. The pattern is monitored, and buoys may be replaced as they expire until

contact is gained or until it is determined that contact was missed [Ref. 2].

Advantages of barrier tactics include:

1. The pattern is easy and quick to lay.
2. Relative buoy positions are accurate.
3. There is a possibility of initial multiple buoy contact.

The disadvantages of barrier tactics include:

1. The effective coverage areas of sonobuoys overlap, which reduces the total area searched.
2. They generally allow only one pass of the target through the pattern.

A distributed field pattern may be more desirable for an on-station submarine if its course and speed are not known and the pattern is based on an area searched.

The general advantages given by distributed field patterns:

1. The area of coverage is large.
2. There is less overlap of effective coverage areas.
3. There can be more than one chance of detection as a submarine transits the area.

Disadvantages of distributed field tactics are:

1. The field is difficult to lay accurately.
2. A long time is required to deploy the field.
3. In a direct path environment, the pattern allows for less course variation than a comparable barrier pattern.

Convergence zone tactics are also based on area coverage. They may be either linear or planar arrays of buoys. In either case, they are based on gaining contact at a range distant from the sonobuoy.

Advantages of convergence zone patterns:

1. The area of coverage is large.
2. A high probability of initial detection is obtained.

The disadvantages of convergence zone patterns include:

1. Localization is difficult.
2. The effectiveness of the patterns are dependent on the environment for existence of reliable convergence zones.

Additional scenario-dependent information which must be evaluated includes the environment and geography of the area, and physical features such as straits or landmasses which may affect the prosecution of the target. In any case, a knowledge of the environment is essential to a timely acoustic localization.

The propagation loss curve is a primary planning tool for the TACCO. Combined with information about the target and sensors, it can be used to develop sonobuoy pattern spacings. There are some inherent problems in using the raw propagation loss curve that arise because there is uncertainty in estimating the figure of merit (FOM).

Actual detection ranges may differ from those forecast due to variations in any or all of the following factors:

1. The choice of acoustic model.
2. Depth of the target.
3. Actual frequency of target.
4. Actual figure of merit.
5. Beam pattern of the target.
6. Other acoustic sources in the area of interest.
7. Accuracy of environmental data.

In a tactical situation, given a sound speed profile of the area and with a recent contact history, a search area can be reduced in size. This reduction of area is based on the concept that although the absolute magnitude of the figure of merit may not be known accurately, nor the actual levels of propagation loss, the acoustic models can give reasonably accurate range information.

While it is obvious that the final objective is to track and attack submarines, a fact which normally requires multiple-buoy contact, a single-buoy contact may be converted to multiple-buoy contact by proper expansion around the buoy in contact. In the event that initial contact is gained on two buoys, much of the localization problem may already be solved. However, setting up a pattern for multiple-buoy initial contact requires many overlapping buoys which decreases the total area covered by the pattern as a whole. For a search pattern to be effective, multiple-buoy contact is not absolutely necessary, since the crew has the means

to deploy expansion buoys. Hence, the measure of effectiveness used in this study will be the probability of detection on a single buoy.

The objective of this thesis is to provide a map of probabilities of detection associated with target position based on estimated target, environmental and sensor parameters.

The output of several of the programs are in the form of topographic maps which are based on a 40 by 40 rectangular grid. The programs allow for variable scales to be used. The scale is defined as relative to the width of the map in nautical miles. The calculations required always use a 40 by 40 grid, allowing for finer resolution when the scale is reduced.

II. DETECTION MODELS

Passive acoustic models use sound speed profiles to determine how sound energy radiating from an acoustic source is horizontally and vertically distributed within the water column. The models also account for target frequency, target and receiver depths, bottom type and sea state. Additionally some models account for semi-coherent or incoherent summing.

A primary output of passive acoustic models is the propagation loss profile, which shows that the signal intensity increases or decreases with range.

A. COOKIE CUTTER DETECTION MODEL

A basic detection model may be constructed using Figure 2.1. By calculating the FOM [Ref. 3], and drawing a horizontal line at that value, the ranges at which PL > FOM are those where the propagation loss profile is above the FOM line. At these ranges, the signal excess is positive and probability of detection is unity (POD = 1). At other ranges, the signal excess is negative and the signal may not be discerned from the noise, hence, the probability of detection is zero. This type of model is called a "cookie cutter detection system". With it the effective area of a sensor has very well defined boundaries.

Figure 2.2 shows the detection probability as a function of range for a cookie-cutter detector. This model is an idealized description of a real system. There are errors made in determining the FOM, which limits the accuracy of this model. The effects of inducing errors in the calculation of FOM are in a large part dependent on the shape of the propagation loss curve. If the slope of the propagation loss curve is great near the intersection of the FOM line, an error of several dB in FOM will not greatly change the effective range of the sonobuoy. If however, the propagation loss curve is flat in the region of intersection, the effective range of the buoy may be markedly different than predicted.

B. GAUSSIAN SIGNAL EXCESS DETECTION MODEL

An improvement to the cookie cutter model is based on the uncertainty in predicted signal excess values. The single look probability of detection is calculated from the predicted signal excess and sigma, the standard deviation of error in its estimation. The Gaussian Signal Excess Model [Ref. 4] assumes the error is normally distributed. The predicted signal excess is calculated from the sonar equation and a value for sigma is chosen, usually between 5 and 10 dB. Reference 5 gives values for typical systems.

By estimating a figure of merit, a signal excess and a value for sigma, a probability of detection plot can be

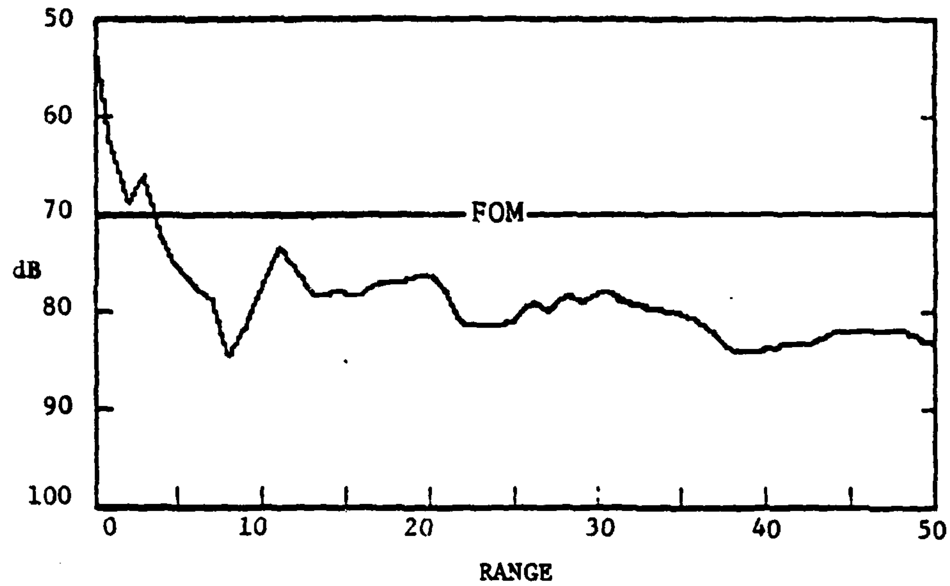


Figure 2.1. A Typical Propagation Loss Profile
ATL050SDS FOM: 70 Sigma: 5

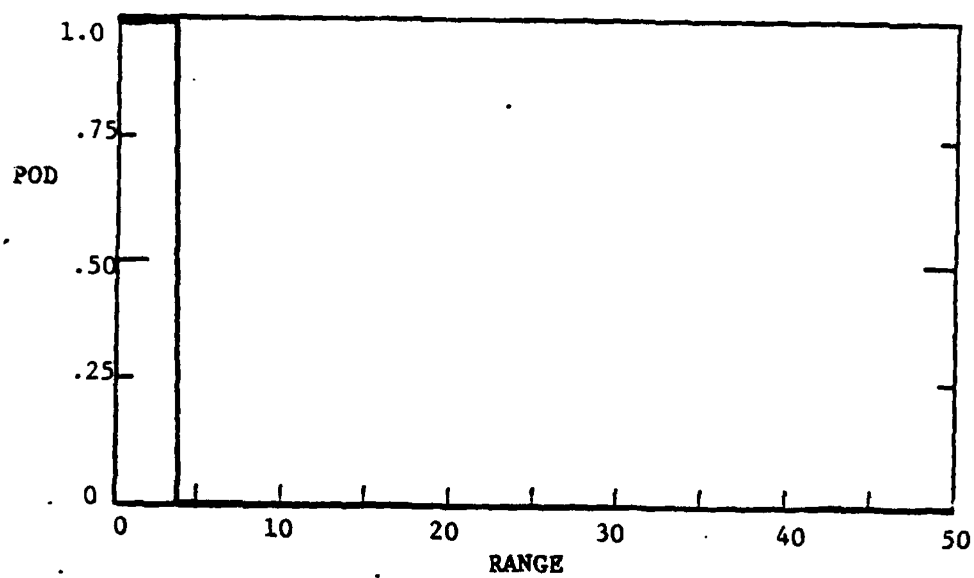


Figure 2.2. Cookie Cutter Detection Model

created. This can be done by comparing the FOM and propagation loss curves at each range to obtain the average signal excess. The average signal excess is then divided by the standard deviation to provide an input value x for computation of the cumulative normal distribution function, $\phi(x)$, since in the Gaussian signal excess model, the probability of detection (POD) = $\phi(x)$.

The cumulative normal distribution function can be approximated by the following expression from Reference 6.

$$\phi(x) = 1 - \tfrac{1}{2} (1 + C_1 X + C_2 X^2 + C_3 X^3 + C_4 X^4)^{-4}$$

where

C1=0.196854, C2=0.115194, C2=0.00034 and C4=0.019527.

Once a plot such as that shown in Figure 2.3 is made, it can be adapted for use in a number of ways. As a pre-flight tool, it will allow a TACCO to visualize the effectiveness of a pattern of deployed sonobuoys. For example, a comparison between the plots for two buoy patterns could help to determine which pattern is the more suitable, or it could indicate whether a pattern allowing small gaps between sonobuoys is preferable to one with no gaps but a smaller area of coverage.

It should be noted that estimates of FOM may vary during the course of a flight. It may be possible for a TACCO to improve the estimated FOM while in the search

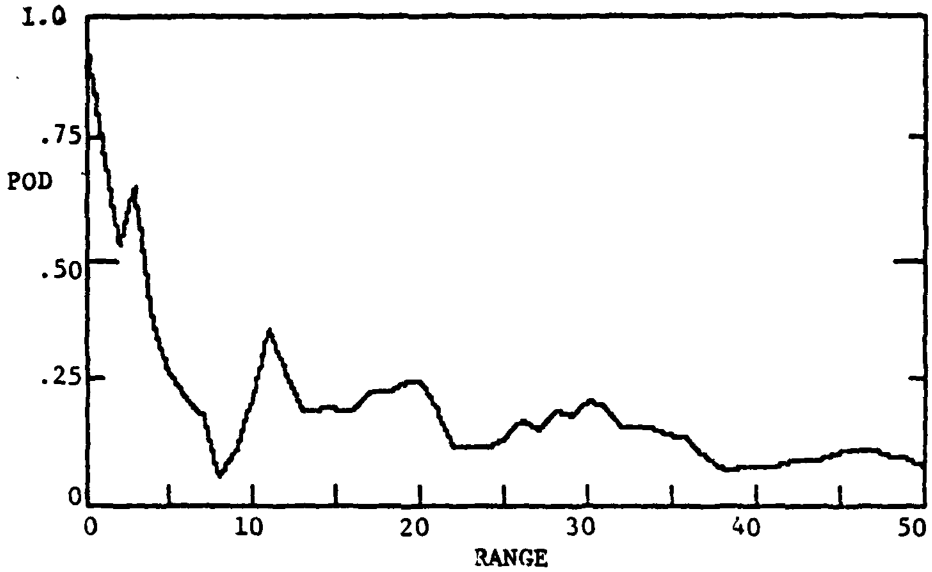


Figure 2.3. Probability of Detection vs. Range
ATL030DDS FOM: 70 Sigma: 5

phase, for example, if the ambient noise meter readings update the value of the ambient noise level. The resulting change in the estimated FOM would also reduce value of sigma.

For localization of a target to be effective, the value of sigma should initially be set as low as can be justified. Setting the value of sigma too high increases the area of ambiguity. While changing the value of sigma alters the probability of detection at most ranges, it does not affect the 50% probability of detection contour (MDR) on which buoy spacing may be based.

III. ORGANIZATION AND OUTPUT OF PROGRAMS

The programs developed for this thesis are designed to give graphic outputs, which may be quickly but accurately interpreted by a trained operator. Graphics are desirable because they can convey much information in a short time. The organization of this analysis makes possible the use of compatible data files to store data that will be calculated by one program and transferred to another. The use of text files allows this storage with a minimum of errors and operator input time. The use of disk storage allows a propagation loss curve to be manually entered once. It is then retrievable for any analysis including a variety of maps and graphs comparing different propagation loss profiles.

Figure 3.1 shows the operational layout of the programs and data files. The inputs to the acoustic model are estimated as in the preparation for a normal preflight briefing. The acoustic model may be any that provides a propagation loss profile.

There are two text file types used and they may be identified by the suffix "-PLF or -HIRES". The suffix is a code identifying the type of data stored in the file. It should be noted that each text file is merely a form of data storage and retrieval and does not operate mathematically on the data.

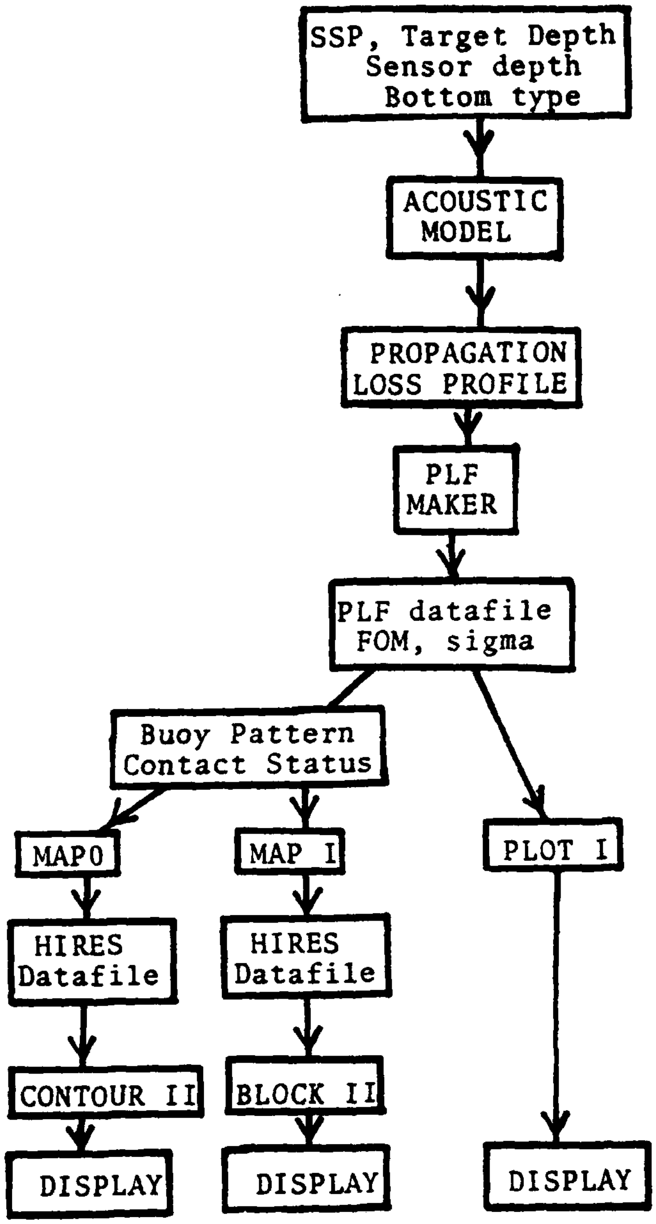


Figure 3.1. Program Data Flow

A. PLF-MAKER PROGRAM

The first program is PLF-MAKER. It prompts the user for a filename and for propagation loss data at one nautical mile increments for ranges of 0 to 50 nm. The operator has the option of correcting the profile prior to final storage. In this analysis the files are coded as follows:

ATL 050 S D s

NNN fff Td Hd s -PLF

NNN - Name of ocean area

ATL - Atlantic
BDA - Bermuda
IOC - Indian Ocean
MED - Mediterranean
PAC - Pacific

fff - Frequency

050 - 50 Hz

Td - Target Depth, S = Shallow D = Deep

Hd - Receiver Depth, S = Shallow D = Deep

s - Summing, s = semi-coherent

i = incoherent

PLF Propagation Loss file

HIRES - High Resolution Plot Datafile

B. PLOT I PROGRAM:

The Plot I program prompts the operator for inputs for two cases. The inputs are propagation loss "-PLF" files, figures of merit and sigmas. The program provides a graphical plot of the propagation loss curve for each

case. This is a graphical plot of the data provided to the PLF-maker program.

A second pair of plots is created by calculating:

$$P\ (SE > 0)$$

for each range increment, which is based on the estimated FOM, sigma and the above propagation loss profile.

A third plot is a difference of probability of detection plot. This may be seen as an improvement plot. It is a point by point comparison of two percentage of detection plots. Positive values indicate that the second case has a higher probability of detection at a given range and a negative value indicates the first plot is more effective at that range. This plot is useful because it shows the TACCO the areas where improvement or degradation may be expected, if the parameters calculated in the FOM may be updated.

Figure 3.2 shows the output from the PLOT I program. In this case it demonstrates the effect of increasing the figure of merit from 73 to 78 dB. This may occur due to the TACCO receiving updated environmental information, changing processing modes, or both. If updated ambient noise values are obtained, the FOM and value of sigma may both change.

This program demonstrates the effects of changing any or all of the parameters used to calculate the probability

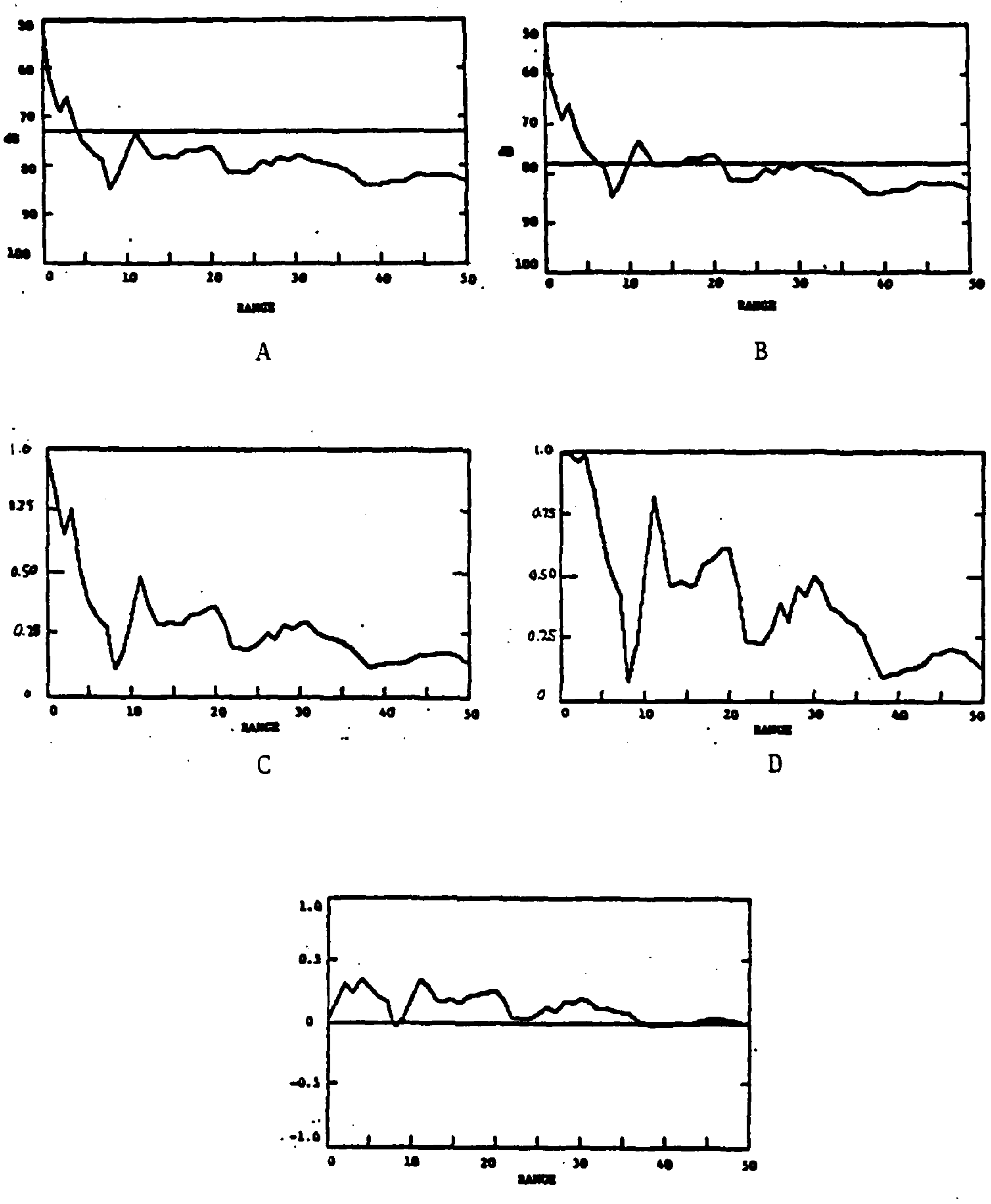


Figure 3.2. Output from PLOT I Program

A. First Propagation Loss Profile
B. Second Propagation Loss Profile
C. First Percentage of Detection Plot
D. Second Percentage of Detection Plot
E. Difference Plot

of detection plot. The program allows the operator to compare two propagation loss files, for example, different models or different frequencies using the same model. Two figures of merit may be compared, or two values of sigma may be used. The results of each of these changes may be computed separately or they may be taken as a group. This program is designed to answer "what if..."-type questions for the operator. It can help him determine those areas in which an error in estimating figure of merit has the greatest effect.

The program may also demonstrate the effects of varying the value of sigma. If the value of sigma is increased, the probability of detection function flattens out and, in an extreme case, approaches 50% for all ranges, giving an ambiguous position. Target contact provides very little localization information.

While the value of sigma is generally taken to be 5 to 10 dB, this program demonstrates the effect of increasing or decreasing sigma. As sigma is decreased, the percentage detection approaches a step function or "cookie cutter" detection system and contact on a single sensor produces a relatively small area of possible locations for the target. In a "real world" situation this could occur if all attributes of the target and environment were well known and if temporal and spatial variations were non-existent. Most often, the cookie cutter model is

used, not because of its accuracy, but because of its simplicity.

A practical use of PLOT I is to compare deep and shallow hydrophones with a given target depth and sound speed profile. This may be used to relate to the operator the advantage of using one or another hydrophone depth setting.

Two values of FOM may be input for the same curve showing the importance of correctly calculating this parameter. This type of analysis can show the operator how much increase or decrease in range he can expect due to changing integration times on the acoustic processor [Ref. 7].

C. MAP SERIES

The output of the MAP series of programs are data files containing probability of detection for an area of the erath's surface. A square shaped area is divided into a 40 by 40 grid, thus giving 1600 cells. The size of the area is determined by the operator input of scale, which is the length of a side. Generally the scale used will be 50 nm, although the programs allow the operator to input any value. If the scale is increased greatly, some resolution may be lost, but in a localization scenario, scales may be successively reduced for better resolution.

The programs use buoy positions in x,y coordinates with values in nautical miles. The center of the plot is 0,0 for all scales. Shown in Figure 3.3. are x and y values for the 50 nm scale.

D. THE MAP 0 PROGRAM

The MAP 0 Program provides a graphical anaylsis of a buoy pattern. The output plot may be used to show the effective extent of a sonobuoy pattern. It also shows how the detection probability varies throughout the area. The highest single buoy percentage detection is plotted, hence the program assumes complete independence among the sonobuoys.

The output is a "HIRES" datafile which is compatible with the CONTOUR II and BLOCK II programs as modified for this project [Ref. 8]. When used with CONTOUR II, the program MAP 0 gives an output of target coverage, which is designed to be useful in mission planning. The pattern drawn indicates areas of high and low probability of contact. The density of the contours indicates the accuracy of the prediction, with closer packing indicating greater accuracy. This may be used to show probability of detection history if the target track is plotted as an overlay on the map.

The isopleths, as shown in Figure 3.4, are lines of equal probability; generally lines will be plotted at

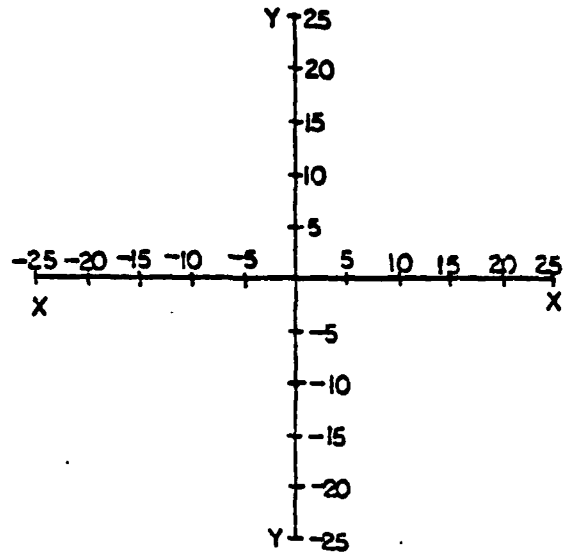


Figure 3.3. Buoy Position Locator, 50 NM Scale

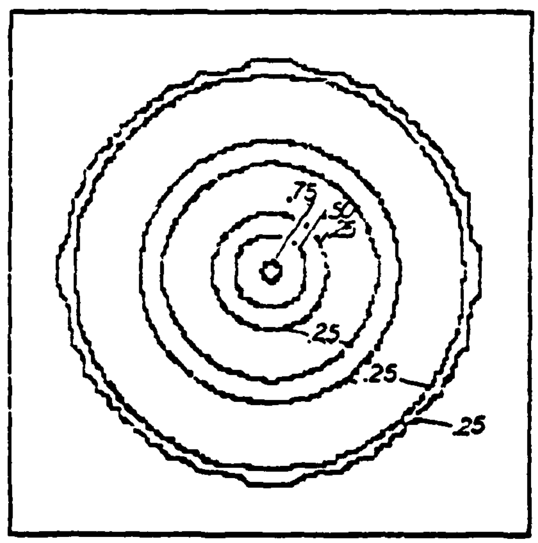


Figure 3.4 CONTOUR II Plot of a Single Sonobuoy Detection Probability

equal intervals. In instances where the slope of the percentage detection plot is very steep, intermediate values may be eliminated for clarity.

In the example shown, the 50% contour is a continuous line indicating that a target may not penetrate the pattern without being exposed to 0.5 probability of contact. This program may be used to give a plot of the target coverage of a complex pattern of sonobuoys. Chapter 5 includes analysis of patterns developed by NADC to test a localization algorithm [Ref. 9]. Various propagation loss profiles are compared for the different patterns.

Figures 3.4 and 3.5 are contour and block representations of probability of detection for a single sonobuoy. The horizontal scale of each of the displays is 50 nm. Figure 3.4 shows two bands within which the probability of detection is greater than 25% located at 12 and 20 nm. The block diagram, Figure 3.5, shows that the rise in probability is slight at those ranges. The probability of detection plot used for this example is from Figure 2.2

An additional use of the MAP 0 plot is in planning simulations. If the known track of the target is plotted directly over the contour chart, the probability of detection may be determined at any time during the run. Single sonobuoy plots may also be made and a determination of the probability of contact on the lower priority sonobuoys may be determined.

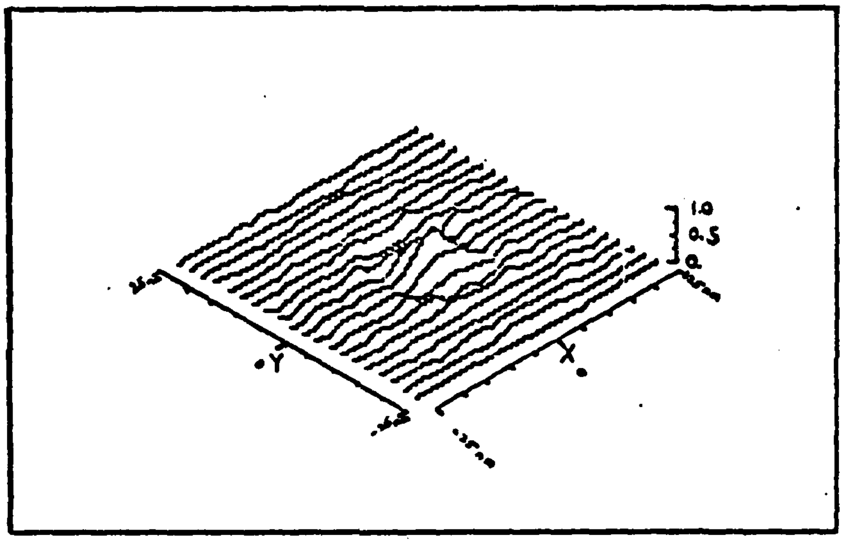


Figure 3.5 BLOCK II Plot of a Single Sonobuoy Detection Probability

E. MAP I PROGRAM

MAP I is the development of a localization algorithm using the propagation loss profile and contact status for determination of position. Any number of sonobuoys may be used and any number of those may be holding contact. DIFAR information is not used by the algorithm.

The algorithm calculates the probability that the buoy status is as observed assuming the target is in the center of each given cell. Positive contact on a buoy causes a peak to be formed near the buoy while negative contact on another buoy causes a depressed area to form in the vicinity of that buoy.

It should be noted that in general the probability of detection at long ranges is near 0, except in convergence zone environments. It may be possible for the operator to delete buoys that clearly have low probability of contact to decrease the run time of the algorithm. These buoys add little information about the possible location of the target.

The probability calculated is equal to the following product:

$$\prod_{1}^{n} \text{POD(buoy in contact)} * \prod_{n+1}^{m} \text{1-POD(buoy in contact)}$$

where n = number of buoys in contact and m = number of buoys in pattern.

The display will indicate the areas to concentrate on as potential sites for additional sonobuoys. The map that is output shows peaks and valleys. The peaks indicate areas of high relative probability of contact. The TACCO may elect to deploy a sonobuoy on one of the peaks in which case, two outcomes are possible for the new (n+1)st buoy. If contact is gained on this new buoy, then POD(n+1) becomes a factor in the above expression. Since this factor is close to 1 for short ranges and close to 0 for distant ranges (assuming no convergence zones), the fact that contact is gained has the effect of decreasing the height of any distant peaks that may exist. If no contact is gained, 1-POD(n+1) becomes a factor. This factor has the opposite effect. The local peak is decreased and distant peaks are not affected. In the existing program it is desirable to eliminate buoys which do not hold contact and which are clearly out of range of the target.

The resultant HIRES file, when plotted by CONTOUR II or BLOCK II, denotes the areas most likely to contain the target for an existing pattern of contact status to arise. Peaks will arise as closed contours. The areas indicated by this map should then be searched by expansion buoys to complete the localization of the target. The accuracy of such a localization algorithm is dependent on how well the acoustic model duplicates the environment.

Single buoy DIFAR contact may be used to aid the TACCO by indicating which of several peaks are most likely to contain the target. However, in the event of unstable or inaccurate bearings, the DIFAR information could hide an otherwise existent peak. In the case where the environment is improperly modeled, this method may not agree with the DIFAR information and confuse a merged routine. In the event that DIFAR contact is held on multiple sonobuoys, a Kalman based localization algorithm such as ASW MUSCLE has been shown to be effective [Refs. 9 and 10].

IV. ANALYSES OF VARIOUS ENVIRONMENTS USING PLOT I

This section describes the origin of the data base used and interprets the output of the PLOT I program. Various acoustic models were used to demonstrate the flexibility of the program. The comparisons that follow are made based on the propagation loss curves using the data in Example I combined with sound speed profiles characteristic of the areas shown. The first comparison is a FACT model propagation loss curve. PLOT I is used to demonstrate the effects that changing the various parameters have on detection probability.

EXAMPLE I. Improvement of Figure of Merit

Filename	:	PAC300DSI
Ocean Area	:	Pacific
Model	:	ASRAPS III
Latitude	:	35 50 N
Longitude	:	133 30 W
Sea State	:	2
Bottom Province	:	3
Sonic Layer Depth	:	500 ft
Target Depth	:	300 ft
Hydrophone Depth	:	90 ft

Figures 4.1 and 4.2 are conventional propagation loss curves. The horizontal line represents the calculated figure of merit. Currently this is the only type of plot available to the TACCO during the preflight phase. The first plot shows an MDR of 7 nm and a possibility of convergence zone detection between 35 and 38 nm. The propagation loss curve rises at that range but it is impossible to determine the likelihood of gaining contact beyond stating that the probability of detection is less than 0.5

Figure 4.2 shows that by increasing the FOM the MDR is increased to 10 nm and an improvement in probability of detection (nearly 0.5), but since the POD was not able to be calculated in the previous case, the amount of improvement still cannot be determined.

Together these plots can be used to show the improvement that may be expected by increasing the FOM from 75 to 78 dB. Determination of the MDR may be made by extending a horizontal line at the 50% probability of detection (see Figures 4.3 and 4.4). This method will also determine the POD in convergence zones. For the direct path portion of the curve, the greatest increase occurs near the MDR. Figure 4.3 shows a 0.20 to 0.25 probability of detection in the convergence zone. By increasing the FOM (Figure 4.4) the POD increases to nearly 50%, a significant increase.

Figure 4.5 is a "Difference Plot". It is a comparison of two percentage detection curves (in this case Figure 4.3

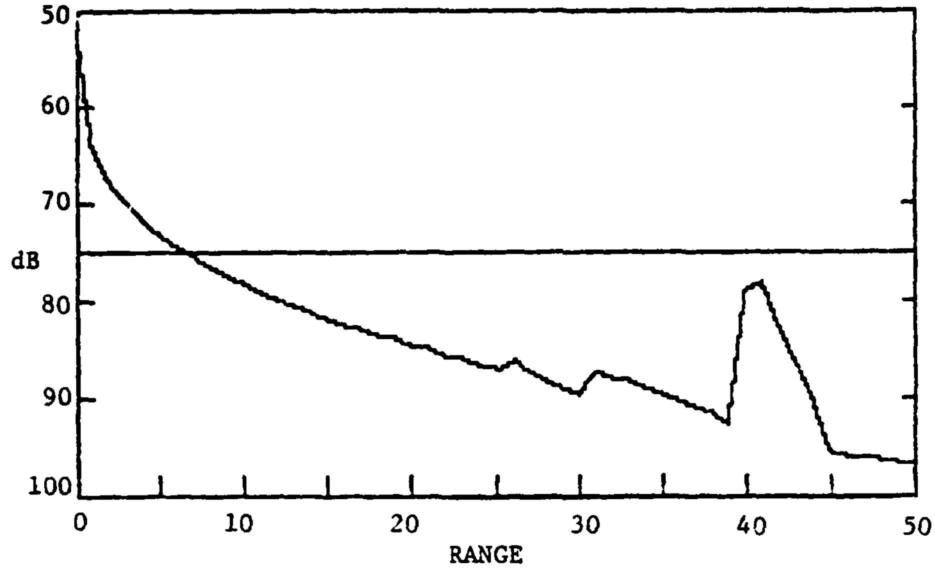


Figure 4.1. Propagation Loss Profile
PAC300DSI FOM: 75 Sigma: 5

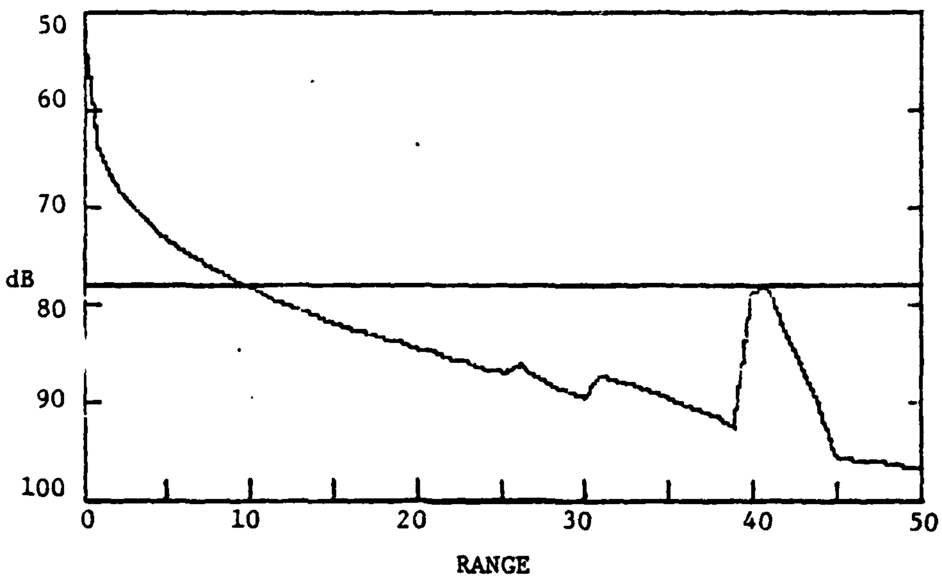


Figure 4.2. Propagation Loss Profile
PAC300DSI FOM: 78 Sigma: 5

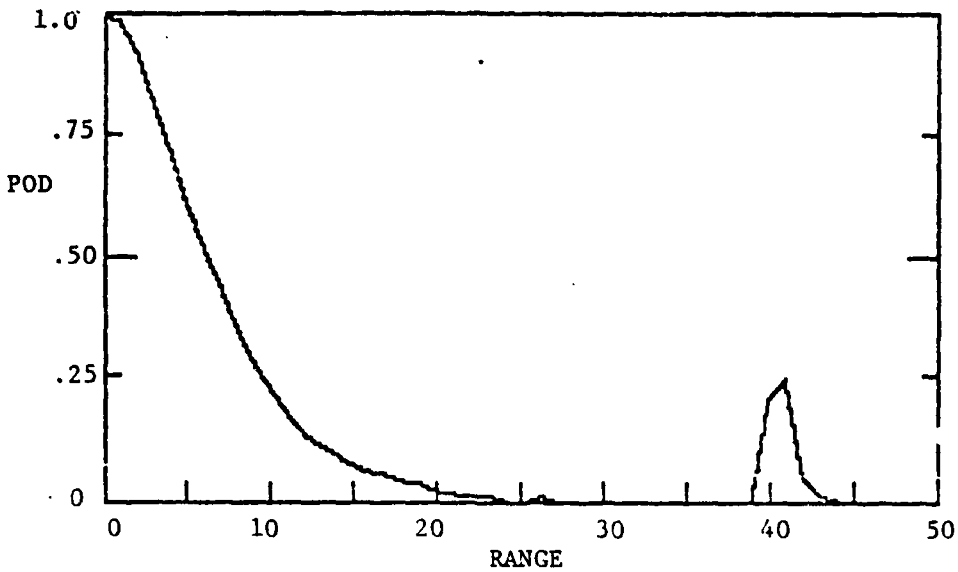


Figure 4.3. Probability of Detection
PAC300DSI FOM: 75 Sigma: 5

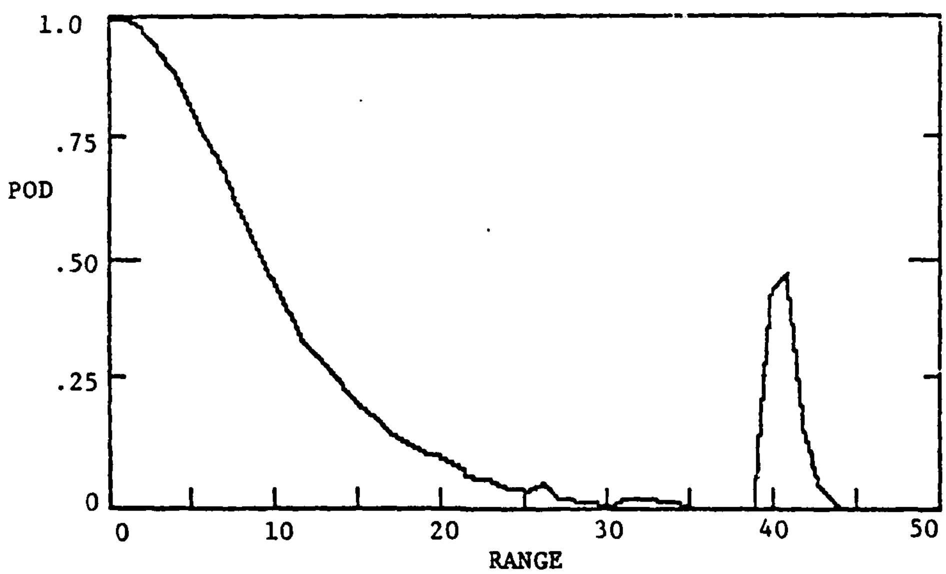


Figure 4.4. Probability of Detection
PAC300DSI FOM: 78 Sigma: 5

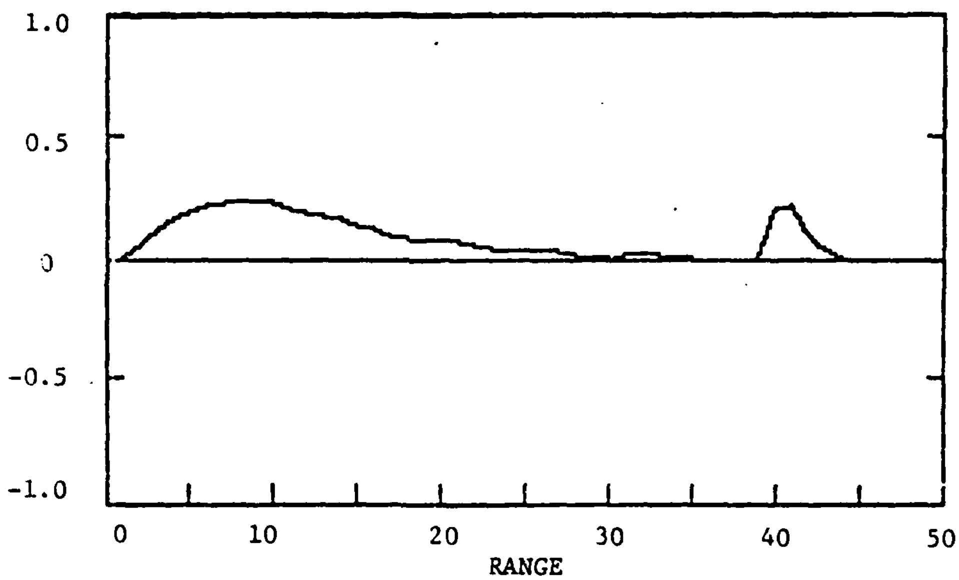


Figure 4.5 Difference Plot:

Case 1	PAC300DSI	FOM:	75	Sigma:	5
Case 2	PAC300DSI	FOM:	78	Sigma:	5

and 4.4). It shows where the two curves are in agreement and where they disagree. This may be interpreted as an "improvement" plot wherein the second data set is compared to the first. In cases where the plot falls below the zero line, the first plot is more likely to gain contact than the second.

EXAMPLE II. Improvement of Figure of Merit

Filename	:	IOC0500DDS
Ocean Area	:	Indian Ocean
Acoustic Model	:	PL-Ray
Latitude	:	03 00 N
Sea State	:	3
Bottom Province	:	3
Sonic Layer Depth	:	100 ft
Target Depth	:	300 ft
Hydrophone Depth	:	1000 ft

Figures 4.6 and 4.7 show a typical Indian Ocean sound speed profile using the data from Example II. The FOM's analysed are 75 and 80 dB. Based on the propagation loss profile, the operator can see that there is a possibility of bottom interaction propagation in both cases. There is a greater probability in the second case but the magnitude of the probability may not be determined.

The next step, Figures 4.8 and 4.9, show that the second case (80 dB) has a greater possibility of detection for all ranges. The areas of greatest improvement occur in the regions of peaks in the propagation loss curve. The probability of contact is improved from less than 25 percent to about 50 percent.

Figure 4.10 shows that a large improvement over most ranges occurs when the FOM is increased from 75 to 80 dB. By comparing Figures 4.8 and 4.9 the MDR does not change appreciably, it stays in the 2 to 3 nm range. However, in the latter case the plot rises and dips greatly, indicating a greater possibility of intermittent or weak contact if the target transits at ranges from 6 to 22 miles from the buoy.

Figure 4.11 is the same propagation loss profile shown in Figures 4.6 and 4.7, but with a FOM of 85 dB. This 5 dB change increases probability of detection through all ranges as shown by Figure 4.12. There is now a 75 percent probability of detection in the bottom bounce regions, and there is also an improved probability of detection at all ranges. Figure 4.13 shows that in this case the improvement from 80 to 85 is of more benefit than that from 75 to 80 for this region. This would give the mission planner an indication of the advisability of using a search pattern based on bottom reflected paths. If he is relatively sure his FOM will be at least as good as 85 dB, he may

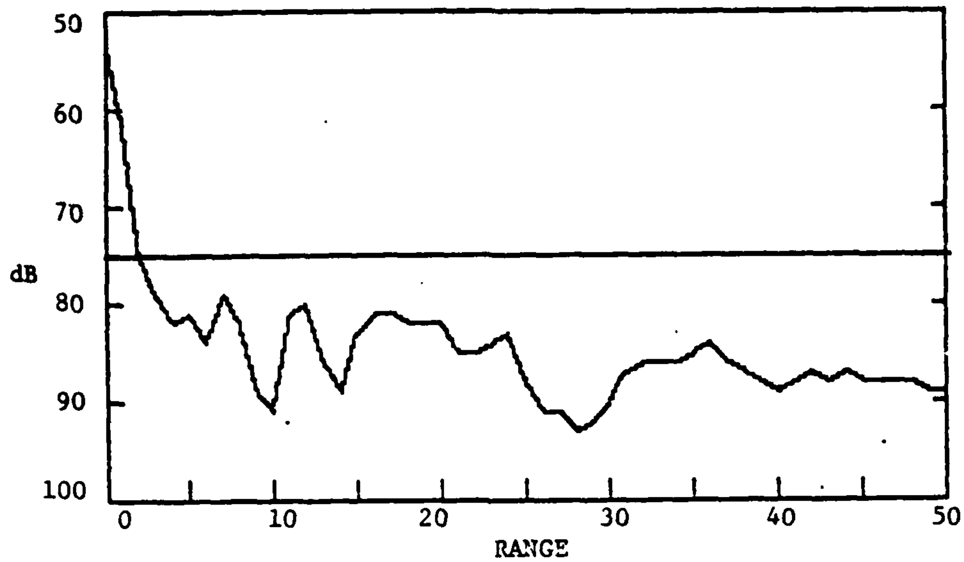


Figure 4.6 Propagation Loss Profile
IOC050DDS FOM: 75 Sigma: 5

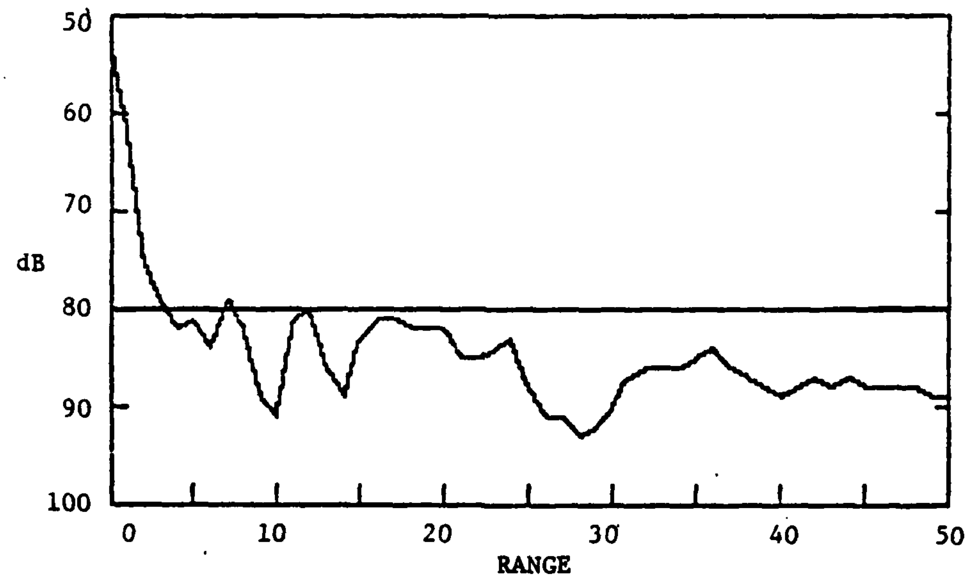


Figure 4.7 Propagation Loss Profile
IOC050DDS FOM: 80 Sigma: 5

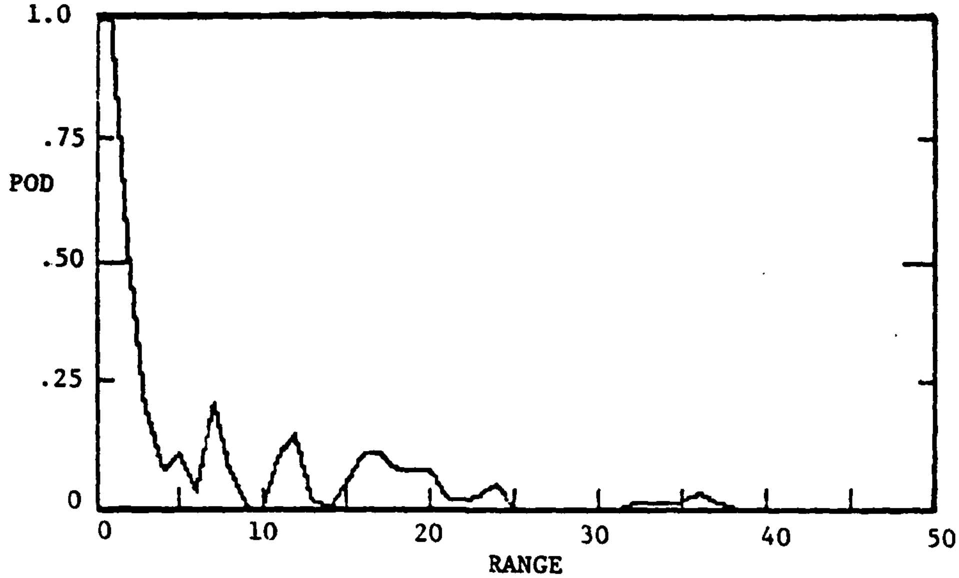


Figure 4.8. Probability of Detection
IOC050DDS FOM: 75 Sigma: 5

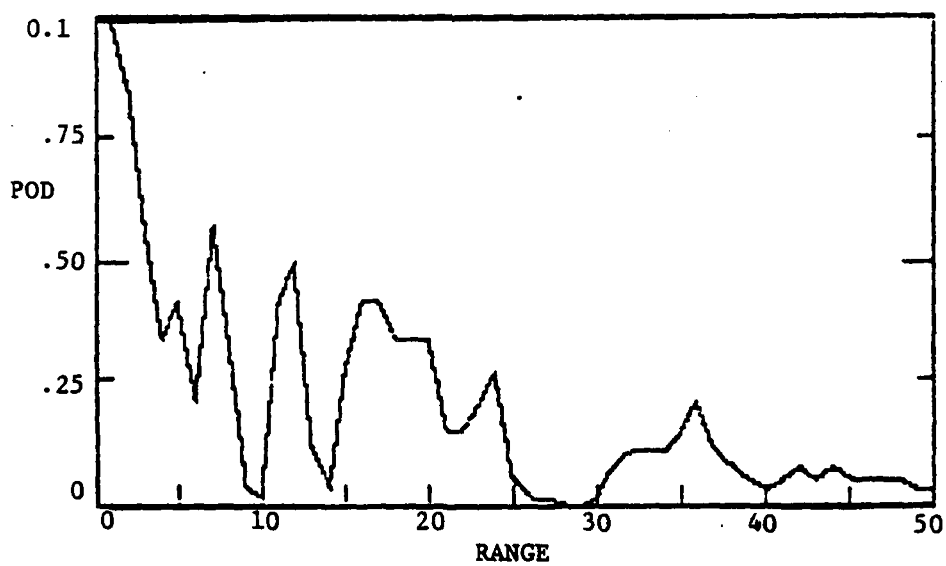


Figure 4.9. Probability of Detection
IOC050DDS FOM: 80 Sigma: 5

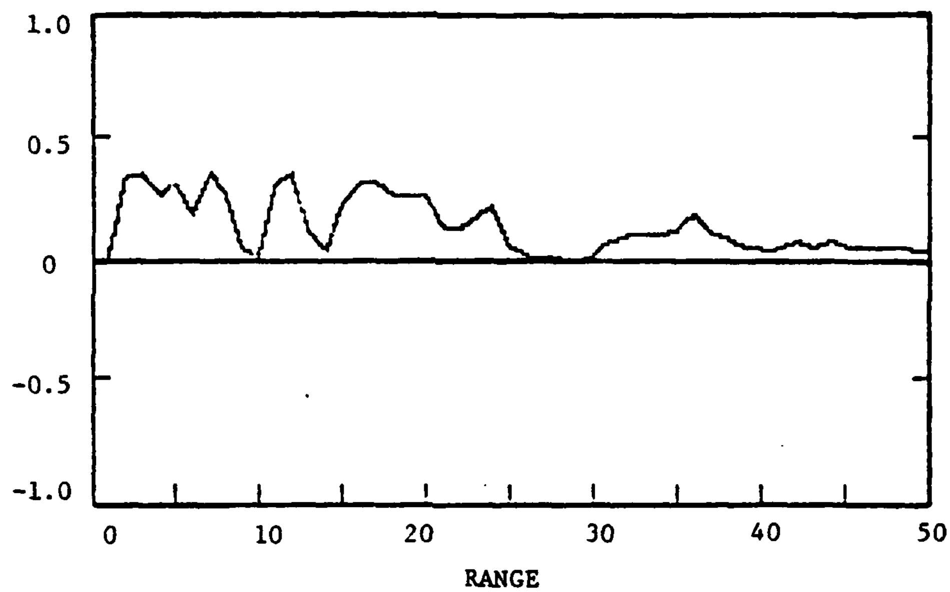


Figure 4.10. Difference Plot
Case 1 IOC300DDS FOM: 75 Sigma: 5
Case 2 IOC300DDS FOM: 80 Sigma: 5

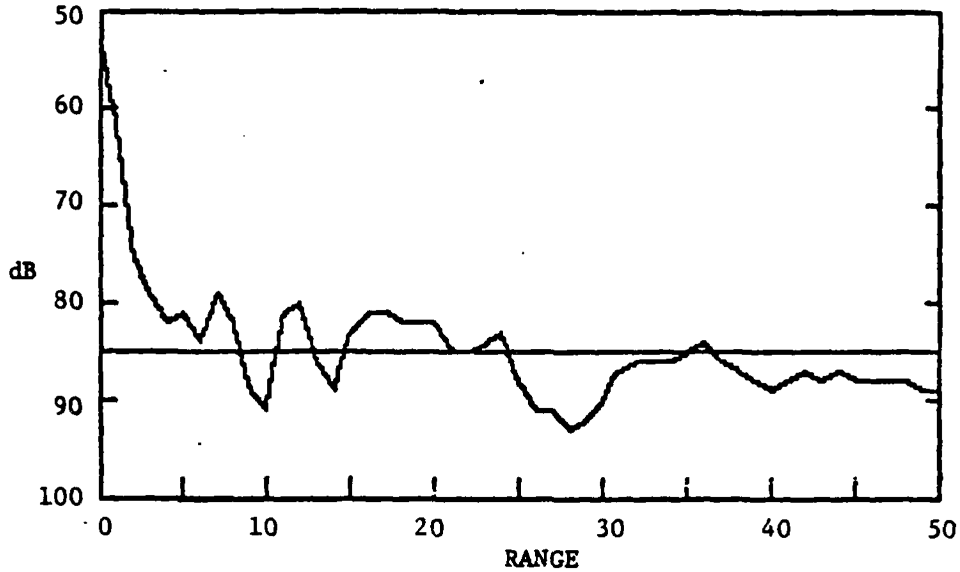


Figure 4.11. Propagation Loss Profile
IOCO50DDS FOM: 85 Sigma: 5

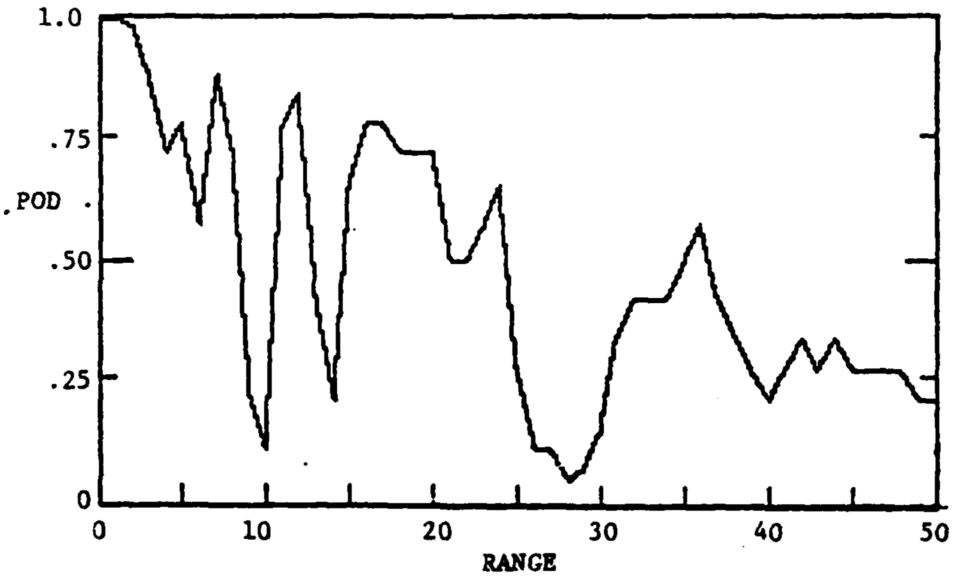


Figure 4.12. Probability of Detection
IOC050DDS FOM: 85 Sigma: 5

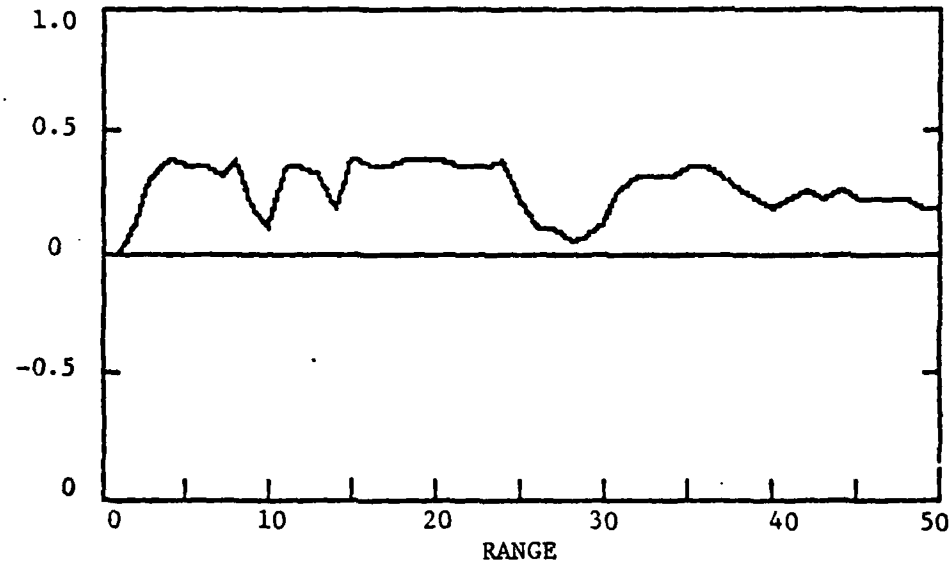


Figure 4.13. Difference Plot
Case 1: IOC300DDS FOM: 80 Sigma: 5
Case 2: IOC300DDS FOM: 85 Sigma: 5

elect to use a larger pattern spacing to increase the total area searched. If he is not confident of the FOM then he should use a direct path pattern although the area coverage is less.

EXAMPLE III. Variation of Sigma

This section uses the same propagation loss profile as Figure 4.6. The two values of sigma used are 10 and 5 dB, the results being shown in Figures 4.14 and 4.15, respectively. It should be noted that when SE = 0 there is no effect on the probability of detection. The effects noted in decreasing the standard deviation is to increase probability of detection in areas of positive SE (0 to 3 nm in this example) and to decrease the probability of detection in areas of negative SE (all ranges greater than 3 nm). When SE has a large absolute value (greater than 2 times the larger sigma) there is little or no affect in decreasing sigma.

In Figures 4.14, 4.15 and 4.16, the same propagation loss profile was used, with only the standard deviation of the FOM changing between the two cases. The difference plot shows an apparent degradation of detection of nearly 20 percent from 5 to 30 nm and a smaller effect at longer ranges. Since decreasing the standard deviation is the same as using a more accurate model, lower probabilities should not be interpreted so much as a "degradation" in the detection capability of the sensor system, but as an increase in the ability of the system to localize, once contact is gained.

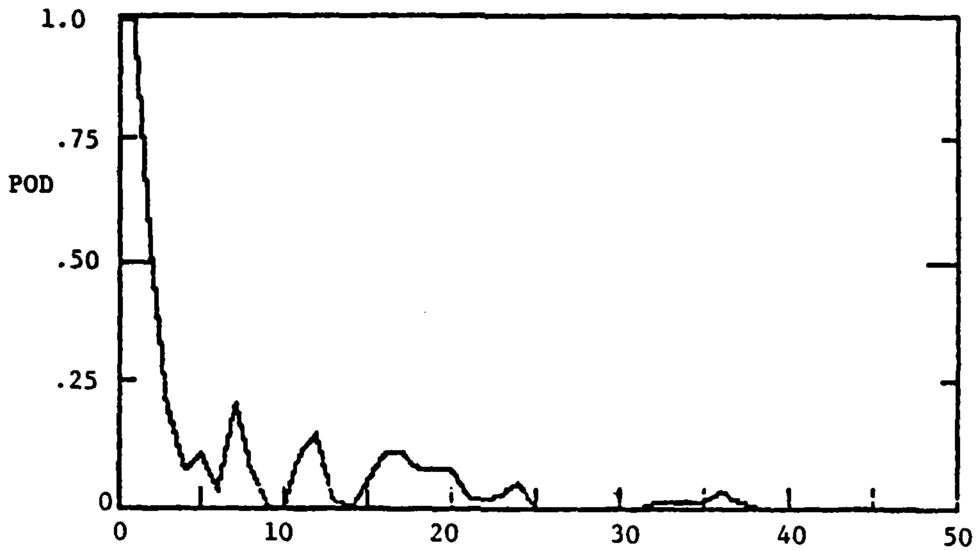


Figure 4.14. Probability of Detection
IOC050DDS FOM: 75 Sigma: 10

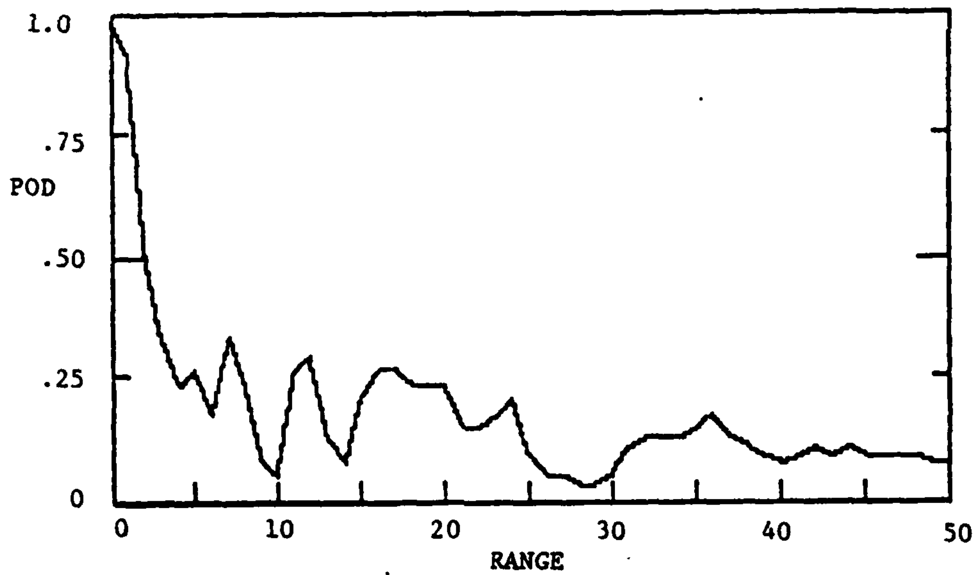


Figure 4.15. Probability of Detection
IOC050DDS FOM: 75 Sigma: 5

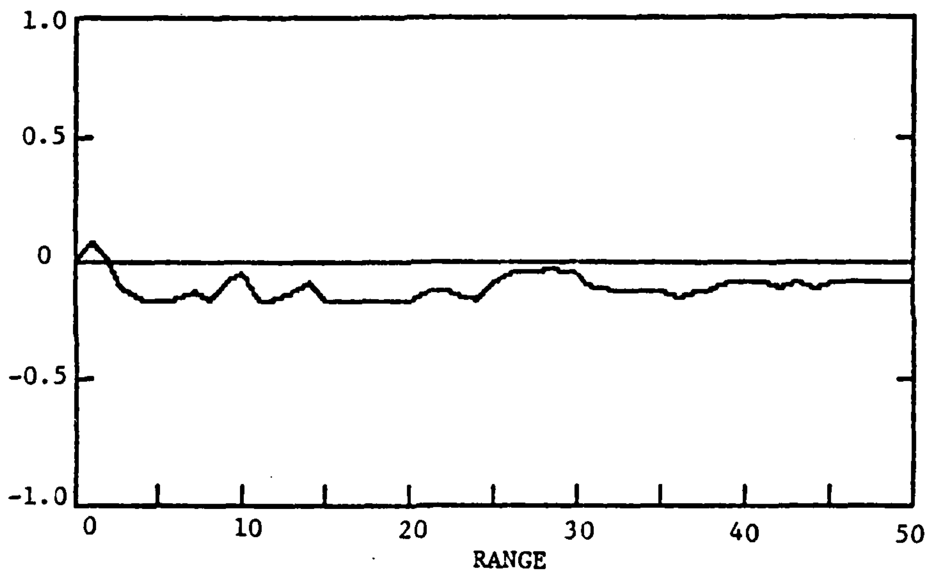


Figure 4.16. Difference Plot
Case 1: IOC050DDS FOM: 75 Sigma: 10
Case 2: IOC050DDS FOM: 75 Sigma: 5

The difference plot is useful because it identifies the areas where knowledge of the environment has the greatest effect on localization. In this case decreasing sigma from 10 to 5 decreases the POD about 20 percent, except at ranges from 25 to 30 nm. This is due to a depression in the propagation loss profile at these ranges.

EXAMPLE IV. Variation of Hydrophone Depth

This case is based on two different propagation loss profiles for the same location. The same model and input information are used for both runs with the exception of hydrophone depth.

Filename	BDA050SDS	BDA050DDS
Ocean Area	Bermuda	Bermuda
Model	PL-Ray	PL-Ray
Latitude	36.00N	36.00N
Bottom Province	4	4
Target Depth	400 ft	400 ft
Hydrophone Depth	90 ft	1000 ft

Figures 4.17 and 4.18 show the propagation loss profiles for both cases. The deep hydrophone case has a longer MDR but it drops more rapidly and fluctuates greatly as range increases. The shallow hydrophone example exhibits a smoother behavior throughout the range. If one inspects the propagation loss curves alone, it is difficult to tell if either depth setting is preferable over all ranges.

Using a FOM of 75 and a sigma of 5 results in the Probability of detection profiles in 4.19 and 4.20. Both are very similar with the exception of a longer MDR and broader CZ for the deep-deep combination.

Figure 4.21 confirms the greatest change difference between the two plots occurs at the short range where the difference is large. At the CZ range, although the deep hydrophone has a broader annulus, the probability of detection is higher on the shallow hydrophone for a short distance. By comparing the percentage of detection plots, the shallow hydrophone shows a maximum of 0.3 POD at the CZ. while the deep shows only a 0.25 POD.

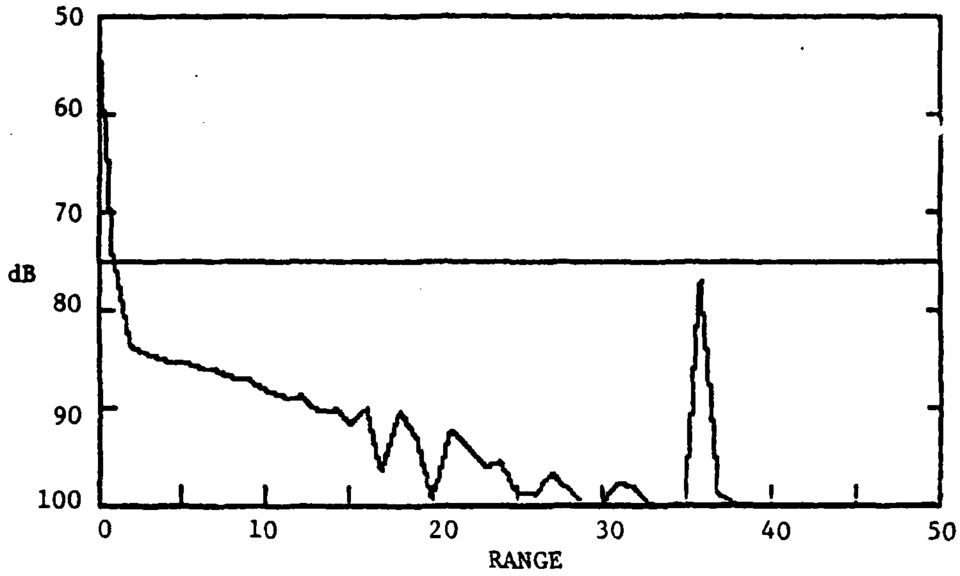


Figure 4.17. Propagation Loss Profile
BDA050SDS FOM: 75 Sigma: 5

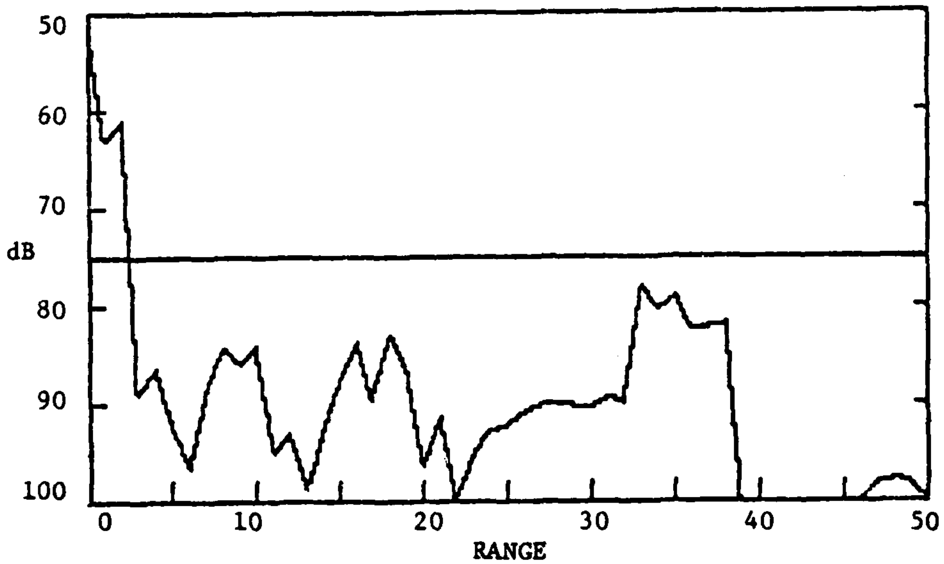


Figure 4.18. Propagation Loss Profile
BDA050DDS FOM: 75 Sigma: 5

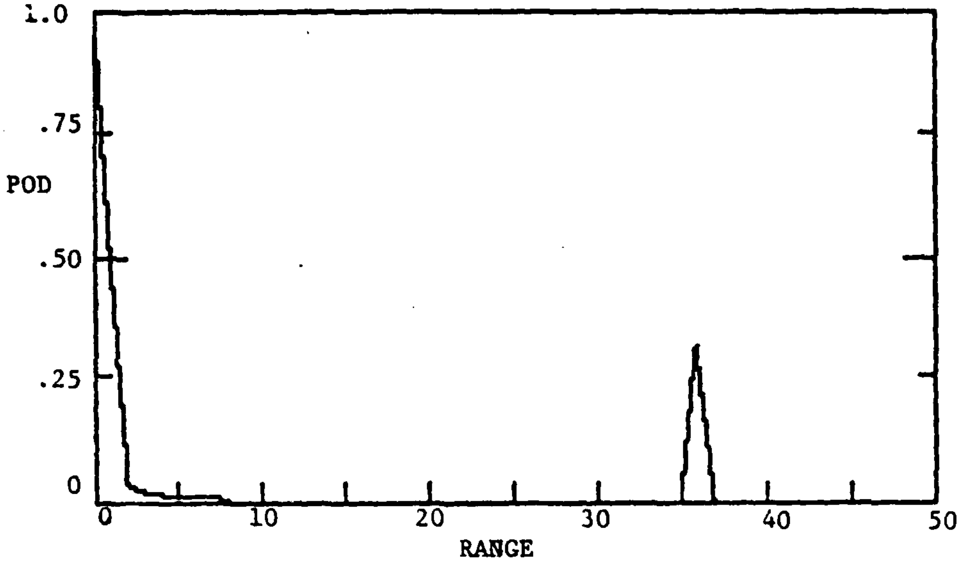


Figure 4.19. Probability of Detection
BDA050SDS FOM: 75 Sigma: 5

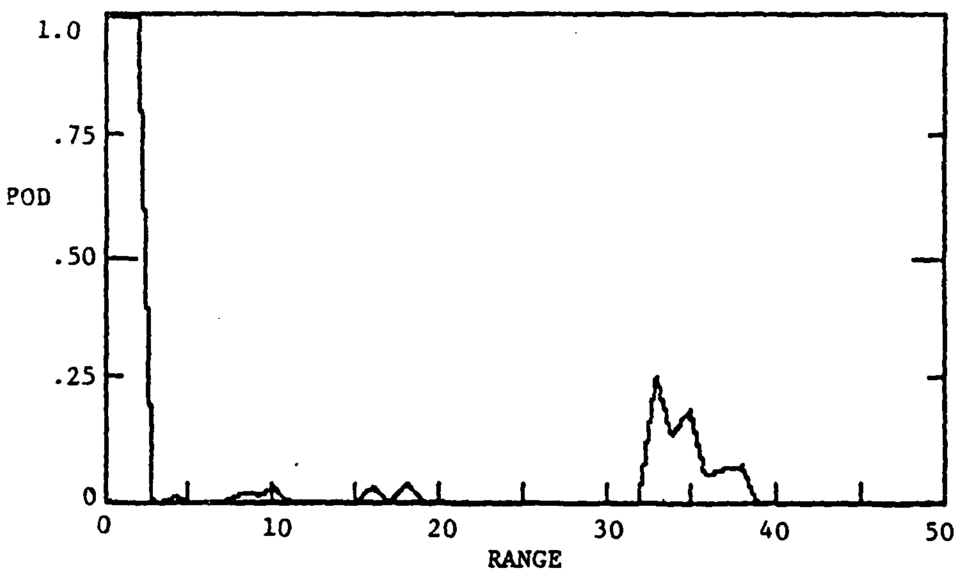


Figure 4.20. Probability of Detection
BDA050DDS FOM: 75 Sigma: 5

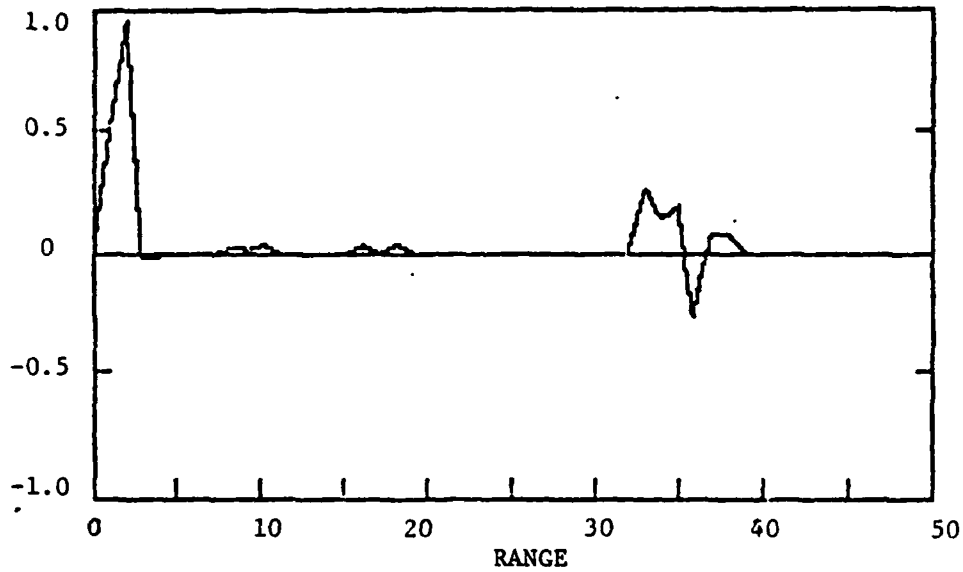


Figure 4.21. Difference Plot
Case 1: BDA050SDS FOM: 75 Sigma: 5
Case 2: BDA050DDS FOM: 75 Sigma: 5

V. COMPARISON OF PATTERN EFFECTIVENESS

This chapter demonstrates the utility of the MAP 0 Program in simulation and in flight planning. The patterns and tracks used were taken from Reference 8 and are typical of those used in initial search. Various propagation loss profiles are used to show how the effectiveness of the patterns are affected by the environment.

Reference 9 showed that certain patterns exhibited variable success in detection and localization. This may be attributed to the fact that the contact effectiveness of a pattern is quite dependent on the environment that is used. In simulation planning the MAP 0 Program allows the initial search pattern and environment to be evaluated prior to the run, by superimposing target tracks directly over the MAP 0 output.

The reader is instructed to refer to Figures 4.1, 4.3, 4.6 and 4.8 for the propagation loss curves and percentage detection plots used to develop the MAP 0 outputs. The PAC300DSI (Pacific Ocean) environment will be used to demonstrate MAP 0 and outputs for appropriate patterns. The same patterns using the IOC300DDS (Indian Ocean) case will be used to demonstrate how the pattern may become inadequate if an alternative environment is used.

Figure 5.1 shows three representative target tracks relative to eight sonobuoy positions. This plot was made using the PAC300DSI propagation loss profile. For simulation planning, a buoy pattern may be input with the required FOM, Sigma and Propagation Loss Curve.

The first environment (Figure 5.1) makes an efficient pattern, suitable for both detection and localization. Target #3 enters the pattern from the East and the probability of detection rises until CPA on the first sonobuoy. The 50% contour is an unbroken line and the 70% contour is large, although broken, the target may not move within the pattern without being exposed to at least 50% POD.

In the second environment (Figure 5.2) it may be noted that target #3 has a very high probability of detection on the first buoy along his path but that the target never quite reaches the 50% contour on the second buoy before turning. This probability of gaining a detection on the third buoy is even lower. The pattern is clearly not adequate for this environment. The gaps are large and it is likely that a target could enter the pattern and be missed entirely.

Using MAP 0 and visualizing possible paths through the pattern, the TACCO may predict the effectiveness of the sonobuoy pattern and identify any weaknesses. By changing the buoy spacing, the TACCO can change the effectiveness

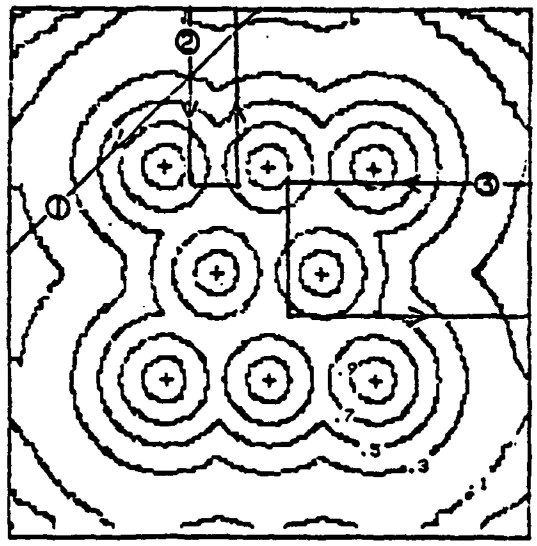


Figure 5.1. MAP 0 Output of Distributed Field Pattern with Target Track Overlay PAC300DSI

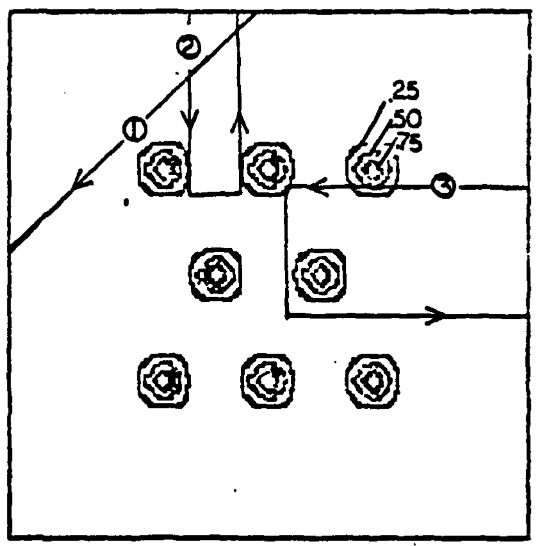
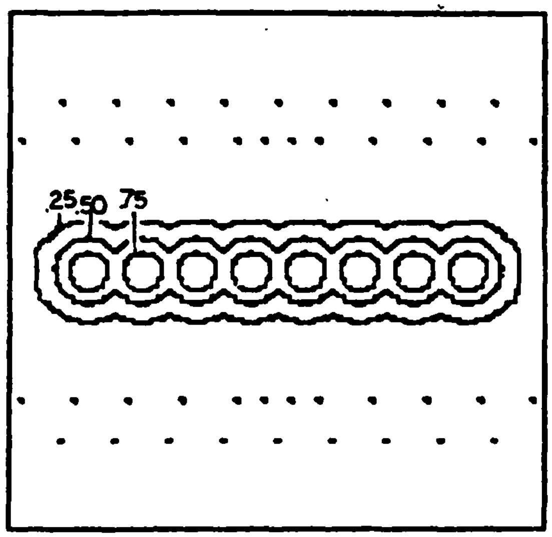


Figure 5.2. MAP 0 Output of Distributed Field Pattern with Target Track Overlay IOC300DDS

of the patterns. The crew is limited in the number of buoys that can be monitored effectively and decreasing the spacing decreases the total area that can be searched. Using this map and estimating the target's position or probability area, the TACCO has a graphical display of the effectiveness of his pattern and any gaps in coverage that may exist.

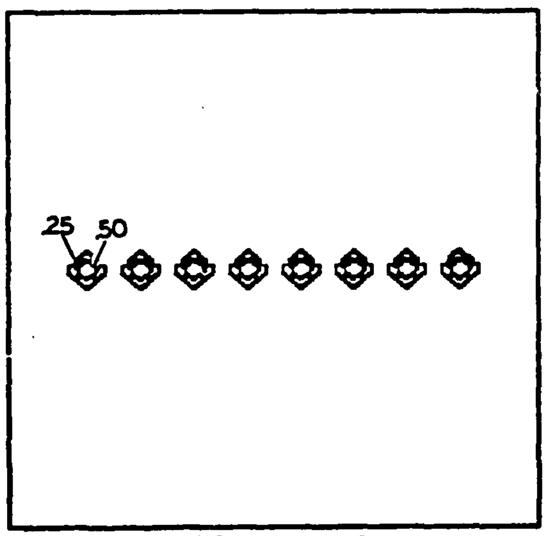
A typical barrier pattern is shown in Figure 5.3 The plot shows that in this case there are "gaps" in coverage between the buoys where the probabiliby of detection falls below 50%. This may be remedied by decreasing the spacing between buoys, however, that will also decrease the width of the search area. In flight planning the apriori distribution of the target may be used to determine if the pattern should be compressed.

If the apriori distribution is large compared to the buoy pattern, the gaps that exist may vary in size and extent. The example in Figure 5.3 has gaps that are relatively narrow, only one tenth of the buoy spacing, and relatively unimportant, the probability of detection is 40% at its worst. The example in Figure 5.4 shows the same spacing, but in this environment, the pattern is much less effective, there are large gaps and a target penetrating the barrier may see a probability of detection as low as 10%.



100 nm scale

Figure 5.3. MAP 0 Output of Barrier Pattern PAC300DSI



100 nm scale

Figure 5.4 Map 0 Output of Barrier Pattern IOC300DDS

VI. DEVELOPMENT OF MAP I, A LOCALIZATION AID

The output of the MAP I Program is a topographic representation of the probability of detection calculated over the surface. The program displays a surface based on either positive (C) and negative (N/C) contact or positive information alone. The input is the propagation loss profile, FOM, sigma, buoy pattern and contact status.

For each of the 1600 cells, the program computes a probability and assigns the value to the respective cell. A representative 3 buoy pattern would allow the surfaces based on the possible contact status combinations as shown below:

Buoy Status			Parameter Calculated
#1	#2	#3	
C	N/C	N/C	POD(1)*(1-POD(2))*(1- POD(3))
C	C	N/C	POD(1)*POD(2)*(1-POD(3))
C	C	C	POD(1)*POD(2)*POD(3)

The single look probability of detection is calculated as if the target were located in each cell and the resultant number assigned to the cell. The probability surface is plotted. Peaks on this surface are indicative of areas of high relative probability of detection.

It was noted that on some propagation loss profiles values may change by 20 dB over a short range. To avoid

missing a peak the probability of detection as a function of range is replaced by an envelope function which takes the greatest of 3 POD computations for each range.

That is, for each rane, r:

Max(POD(r-1 nm),POD(r),POD(4+1 nm))

where r is in nautical miles

is calculated for the probability of detection function for buoys in contact. A similar function is calculated for buoys not in contact:

Max(1-POD(r-1 nm),1-POD(r),1-POD(r+1 nm))

The result of using the envelope functions are larger probability areas, but they decrease the problem of missing detections due to a greatly varying environment or a rapidly fluctuating propagation loss curve. Although it increases the area that remains under suspicion, it reduces the effects of underestimating the propagation loss curve which could lead to missing an area of high detection probability. This method also decreases the problem of inaccuracies in range of the propagation loss curve.

The program has the ability to use positive and negative information, that is, buoys holding contact will increase the value of the probability in the local vicinity and decrease it at longer ranges. A buoy not holding contact will decrease this parameter primarily at close ranges. The

effect at long ranges will be much less. If two buoys are in close proximity with the first holding contact, the surface will peak near the first but will be skewed away from the second. Figure 6.1 shows such a case. This method seems to be most effective when only one or two buoys are holding contact.

A second possibility is to accept only positive data. This is less accurate but run time is decreased. It may only be effective when two or more buoys are holding contact. In such a case, the absolute values of the entire surface may decrease drastically because most of the probabilities are much less than 1, and when multiplied decrease greatly. Peaks still occur where high probability areas intersect. Figure 6.2 shows the same pattern as above, with both buoys holding contact. The peak has now shifted from outside of the two buoys to the center of the two buoys. This information may be used by the TACCO to plan expansion buoys. If DIFAR information is available, it should decrease the size of the probability area even further.

The following development shows the operation of the MAP I program as a target passes through a buoy field. The target and pattern (Figure 6.3) are taken from Reference 10, run 17. It should be noted that the output of the program is predictable from the contact status alone and is not dependent on the observed signal excess. If, for example, the FOM were less than predicted, the contact status would

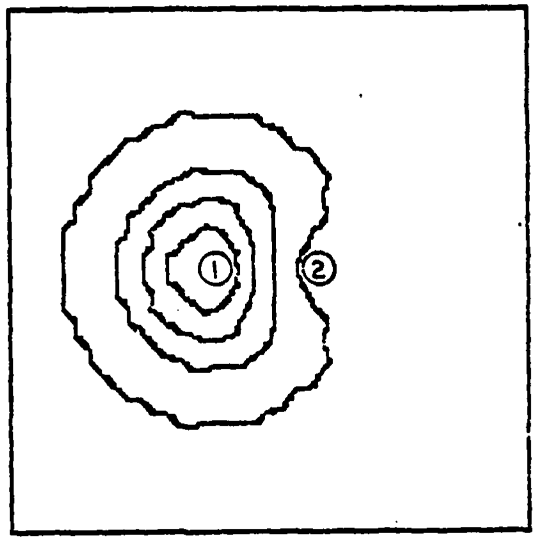


Figure 6.1. MAP 1 Plot, Two Sonobuoy Pattern.
Buoy #1 Holding Contact.

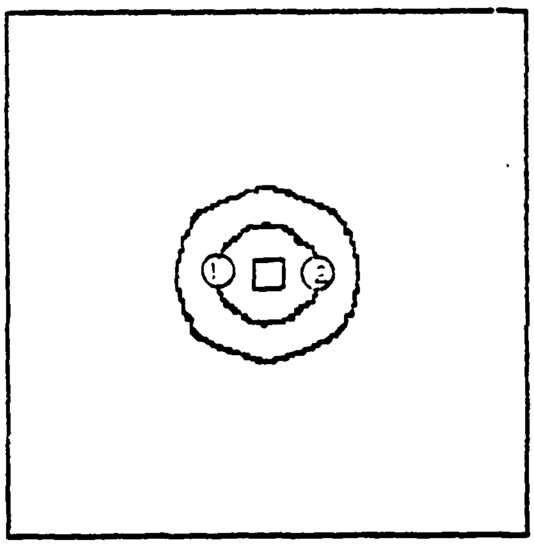


Figure 6.2. MAP I: Two Buoy Contact

change at different times, but as long as the buoys gained contact, the MAP I output would be the same.

The track used here is the same as track 3 in Figure 5.3. As the target enters the buoy field, initial contact is gained on buoy #3. Figure 6.4 shows the MAP 1 output when contact is initially gained. The peak is skewed to the east, away from the rest of the pattern, since contact is held only on one buoy.

As the target proceeds along its westward track, contact is gained on buoy #2. Figure 6.5 shows the output of MAP I with this new information. The peak is between the two contact buoys but is slightly north of the target's track. In this case the peak is close enough to the target to give adequate localization.

After the target turns, contact is gained on buoy 5. This causes the peak to shift to the south and is positioned roughly in the center of the three contact buoys (Figure 6.6). Again the peak is near the track of the target.

As the target continues, contact may be held briefly on four buoys. In that case the output would look like Figure 6.7. In the event contact was lost on any one of the four, the peak would be moved away from the individual sonobuoy.

The MAP I program could be used in localization to help the TACCO determine where to lay the next sonobuoy when initial contact is gained. Given the current buoy contact

status, he may add an additional buoy at or near the peak. This buoy has two possibilities; it either will gain contact or it will not. In the first case the peak will be slowed to a position between the buoys in contact. If contact is not gained, the buoy peak will be depressed and other lesser peaks will remain. The TACCO may then deploy sonobuoys in the vicinity of these until multiple buoy contact is achieved. The advantage of this program is that it gives the ability to proceed in a logical order to investigate areas of probability.

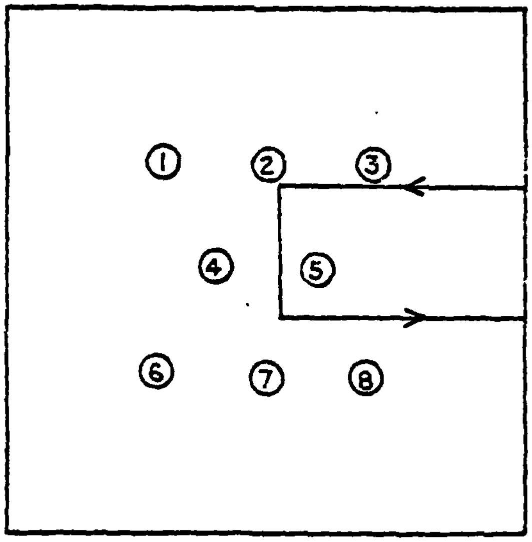


Figure 6.3. Sonobuoy Pattern and Track of Target

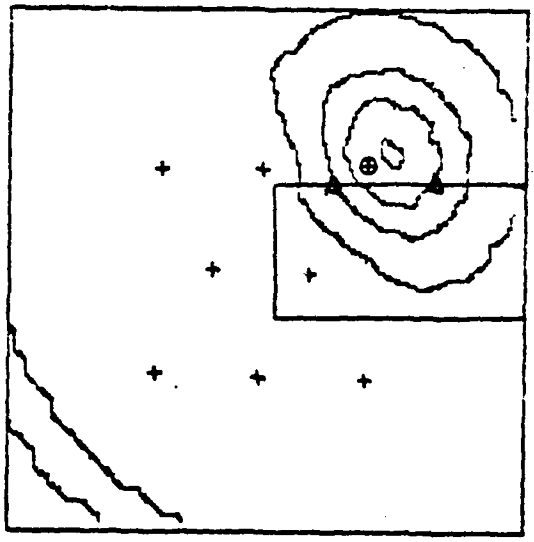


Figure 6.4 Contact Gain on Buoy #3

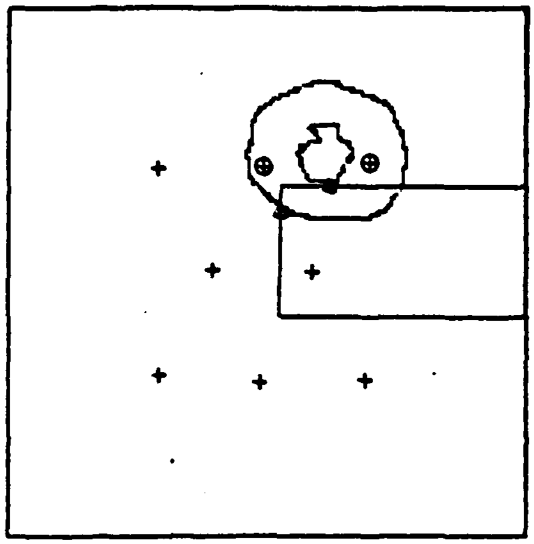


Figure 6.5. Contact Held on Buoys #2 and #3

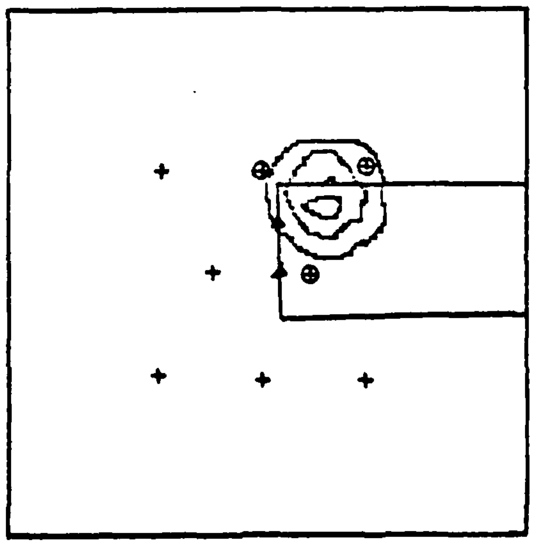


Figure 6.6. Contact Held on Buoys #2, #3 and #5

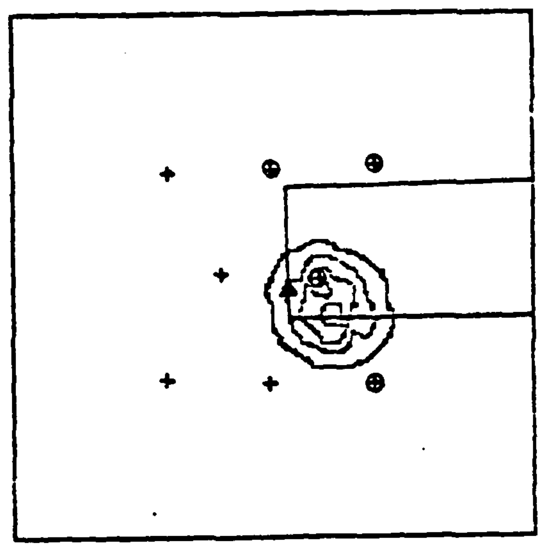


Figure 6.7. Contact Held on Buoys #2, #3, #5 and #8

VII. CONCLUSIONS

Various products can be created by using the signal excess model. The plots produced by the programs based on this model utilize microcomputer graphics to provide information which may be used to optimize sonobuoy employment. The inputs required are a propagation loss profile, a figure of merit and a standard deviation of the signal excess. The plots shown can indicate the effectiveness of a sonobuoy pattern.

The localization program has several potential advantages. These include the following:

1. It is independent of DIFAR processing.
2. It leads the aircrew to areas of high probability.
3. It may be used in direct path, bottom bounce and convergence zone environments.
4. An inflight version could use bathythermographic data coupled with an acoustic model to produce more accurate results.
5. It is flexible in that it may be used in any environment.

There are also a number of limitations that are evident:

1. It requires long run times. Machine level programming could help an operational program give a real time output.
2. It requires much interaction to input data. Direct computer interfacing that currently exists could be used in an operational program.
3. As with any localization program, false alarms and missed detections could have an adverse effect on the program.

There are also some considerations that could be incorporated to improve the efficiency of the localization program. Multiple propagation loss profiles would allow the correlation of different frequencies. A directional ambient noise model such as the DANES model would add some capability. However, DANES would increase the required run times, since it would need a much larger matrix to describe the directional percentage detection profile.

APPENDIX A

The following program listings will provide the plots shown in this thesis. The programs are written in Applesoft BASIC and require an Apple II computer with 48K and a single disk drive. For the BLOCK II and CONTOUR II programs only the changes required to convert them from the BLOCK and CONTOUR from Reference are listed.

PLF-MAKER PROGRAM LISTING

```
10  DIM PL(50)
20 D$ =  CHR$ (4)
30  INPUT "NAME OF PROPLOSS CURVE FILE :";N$
40  FOR I = 0 TO 50
60  PRINT "INPUT PROPLOSS AT ";I;" NM: ";: INPUT "";
    PL(I)
70  NEXT I
80  PRINT D$"OPEN ";N$ + "-PLF"
90  PRINT D$"WRITE ";N$ + "-PLF"
100  FOR I = 0 TO 50
110  PRINT PL(I)
120  NEXT I
130  PRINT D$"CLOSE ";N$ + "-PLF"
135  GOSUB 300
140  INPUT "ANY CORRECTIONS (Y/N) ?";A$: IF A$ = "N"
     THEN 200
150  INPUT "RANGE : ";R
160  INPUT "PROP LOSS VALUE : ";PL(R)
170  INPUT "ANY MORE CORRECTIONS (Y/N) ? :";A$: IF A
    $ = "N" THEN 80
130  IF A$ = "Y" THEN 150
200  END
300  PRINT D$"OPEN ";N$ + "-PLF"
310  PRINT D$"READ ";N$ + "-PLF"
330  FOR I = 0 TO 50
340  INPUT PL(I)
350  NEXT I
355  SPEED= 100
360  FOR I = 0 TO 49 STEP 2
370  PRINT I,PL(I),PL(I + 1)
380  NEXT I
385  PRINT 50,PL(50)
390  PRINT D$"CLOSE "N$ + "-PLF"
394  SPEED= 255
400  RETURN
```

PLOT I PROGRAM LISTING

```
10 R2 = 50
20 D$ =  CHR$ (4)
110 C1 = .196854:C2 = .115194:C3 = .000344:C4 = .019
    527
120  FOR I = 1 TO 2
140  PRINT "INPUT NAME OF FILE #";I;" :";: INPUT "";
    NA$(I)
150  PRINT "INPUT FOM (";I;: INPUT ") :";FM(I)
160  PRINT "INPUT STANDARD DEVIATION (";I;: INPUT ")
    : ";SG(I)
170  NEXT I
200  DIM PL(2,R2),Q(2,R2),DF(R2)
300  FOR J = 1 TO 2
310  PRINT D$"OPEN ";NA$(J) + "-PLF"
320  PRINT D$"READ ";NA$(J) + "-PLF"
330  FOR I = 0 TO R2
340  INPUT PL(J,I)
350  NEXT I
360  PRINT D$"CLOSE ";NA$(J) + "-PLF"
370  NEXT J
600  DEF  FN P(X) = 1 - (1 / (2 * (1 + C1 * X + C2 *
    (X ^ 2) + C3 * (X ^ 3) + C4 * (X ^ 4)) ^ 4))
610  FOR I = 0 TO 50
620  FOR J = 1 TO 2
630 SE(J) = FM(J) - PL(J,I)
650  IF SE(J) >  = 0 THEN Q(J,I) =  INT (100 *  FN P
    (SE(J) / SG(J))): GOTO 665
660 Q(J,I) =  INT (100 - (100 *  FN P( - SE(J) / SG(
    J))))
665  NEXT J
670  NEXT
700  FOR I = 0 TO R2
710 DF(I) = Q(1,I) - Q(2,I)
720  NEXT I
4020  FOR J = 1 TO 2
4025  HGR
4027  HCOLOR= 3
4028 PN = 1
4030  HPLOT 0,0 TO 0,150 TO 279,150 TO 279,0 TO 0,0
4040  HPLOT 0,30 TO 5,30: HPLOT 275,30 TO 279,30: HPLOT
    0,60 TO 5,60: HPLOT 275,60 TO 279,60
4050  HPLOT 0,90 TO 5,90: HPLOT 275,90 TO 279,90: HPLOT
    0,120 TO 5,120: HPLOT 275,120 TO 279,120
4060  FOR I = 5 TO R2 STEP 5
4070  HPLOT I * 279 / R2,144 TO I * 279 / R2,149
4080  NEXT
```

```
4085  HPLOT 0,(3 * FM(J) - 150) TO 279,(3 * FM(J) -
    150)
4087  IF PL(J,0) < 50 THEN  HPLOT 0,0: GOTO 4100
4090  HPLOT 0,3 * (PL(J,0) - 50)
4100  FOR I = 1 TO R2
4105  IF PL(J,I) < 50 THEN  HPLOT I * 279 / R2,0: GOTO
    4130
4110  IF PL(J,I) > 100 THEN  GOTO 4125
4120  HPLOT  TO I * (279 / R2),3 * (PL(J,I) - 50): GOTO
    4130
4125  HPLOT  TO I * 279 / R2,150: GOTO 4130
4130  NEXT I
4150  PRINT
4160  PRINT "PROPLOSS CURVE ";NA$(J)
4170  PRINT "FOM : ";FM(J);"     SIGMA : ";SG(J)
4175  INPUT H$: IF H$ = "P" THEN  GOSUB 5000
4180  NEXT J
4215  FOR J = 1 TO 2
4220  HGR
4225 PN = 2
4230  HPLOT 0,0 TO 0,150 TO 279,150 TO 279,0 TO 0,0
4240  HPLOT 0,75 TO 10,75: HPLOT 269,75 TO 279,75
4250  HPLOT 0,37 TO 5,37: HPLOT 274,37 TO 279,37
4260  HPLOT 0,111 TO 5,111: HPLOT 274,111 TO 279,111

4261  FOR I = 5 TO R2 STEP 5
4262  HPLOT I * 279 / R2,144 TO I * 279 / R2,149
4263  NEXT
4270  HPLOT 0,150 - 1.5 * Q(J,0)
4280  FOR I = 1 TO R2
4290  HPLOT  TO I * (279 / R2),150 - 1.5 * (Q(J,I))
4300  NEXT I
4305  PRINT "PERCENTAGE DETECTION PLOT ";NA$(J)
4306  PRINT "FOM : ";FM(J);"     SIGMA : "SG(J)
4310  INPUT H$: IF H$ = "P" THEN  GOSUB 5000
4315  NEXT J
4420  HGR
4430  HPLOT 0,0 TO 0,150 TO 279,150 TO 279,0 TO 0,0
4440  HPLOT 0,75 TO 279,75
4450  HPLOT 0,37 TO 5,37: HPLOT 274,37 TO 279,37
4460  HPLOT 0,111 TO 5,111: HPLOT 274,111 TO 279,111
```

```
4461  FOR I = 5 TO R2 STEP 5
4462  HPLOT I * 279 / R2,144 TO I * 279 / R2,149
4463  NEXT
4470  HPLOT 0,DF(0) * .75 + 75
4480  FOR I = 1 TO R2
4490  HPLOT  TO I * (279 / R2),DF(I) * .75 + 75
4500  NEXT I
4503 PN = 3
4505  PRINT "DIFFERENCE PLOT "
4506  PRINT NA$(1),NA$(2)
4507  PRINT FM(1),FM(2)
4508  PRINT SG(1),SG(2)
4600  END
```

MAP 0 PROGRAM LISTING

```
2  TEXT : HOME
5  PRINT "                          MAP 0"
10  PRINT : PRINT
15  PRINT "THIS PROGRAM GENERATES A DATA FILE TO"
20  PRINT "BE USED AS INPUT FOR THE TOPOGRAPHIC"
25  PRINT "MAPPING SERIES. THE OUTPUT OF THIS"
30  PRINT "PROGRAM MAY BE SEEN AS A TARGET"
35  PRINT "COVERAGE PLOT.  WHEN USED WITH THE"
40  PRINT "CONTOUR PLOT, VARIOUS VALUES OF PERCENT"
45  PRINT "OF DETECTION MAY BE PLOTTED.
50  PRINT : PRINT "FOR STANDARD ANALYSES, THE ISOLIN
    ES"
55  PRINT "ARE RECOMMENDED TO BE 25, 50 AND 75"
60  PRINT "PERCENT."
90  INPUT "HIT RETURN TO CONTINUE";A$
95  HOME
99  REM  DEFINE CONSTANTS
100 C1 = .196854:C2 = .115194
110 C3 = .000344:C4 = .019527
120 PI = 4 *  ATN (1):R2 = 50
140 D$ =  CHR$ (4)
150 MN = 100:MX = 0
160 TR = 1000
199  REM  INPUT VARIABLES
200  INPUT "NAME OF PROJECT: ";N$
210  INPUT "SCALE OF PLOT: ";SC
240  INPUT "FIGURE OF MERIT :";FM
250  INPUT "STANDARD DEVIATION OF ESTIMATE: ";SG
275  INPUT "NUMBER OF BUOYS IN PATTERN :";N1
280 S1 = SC / 40:S2 = SC / 2:S3 = 2 * SC
290  IF S3 < R2 THEN S3 = R2
299  REM   DIMENSION ARRAYS ****
300  DIM CE(40,40)
310  DIM PD(S3),PQ(S3)
340  DIM BX(N1): DIM BY(N1)
399  REM  INPUT BUOY POSITIONS
400  FOR I = 1 TO N1
410  PRINT "INPUT X,Y OF BUOY # ";I
420  INPUT BX(I),BY(I)
430  NEXT I
```

```
450  HOME
460  INPUT "PROP LOSS FILENAME (DEL -PLF): ";B$
470  PRINT D$"OPEN ";B$ + "-PLF"
480  PRINT D$"READ ";B$ + "-PLF"
510  FOR I = 0 TO R2
520  INPUT PQ(I)
540  NEXT I
545  PRINT D$"CLOSE ";B$ + "-PLF"
546  IF S3 < = 50 THEN 600
550  FOR I = R2 + 1 TO 2 * SC
560 PQ(I) = 99
570  NEXT I
599  REM  CONVERT PROP LOSS CURVE TO PROBABILITY OF
    DETECTION CURVE
600  DEF  FN P(X) = 1 - (1 / (2 * (1 + C1 * X + C2 *
    (X ^ 2) + C3 * (X ^ 3) + C4 * (X ^ 4)) ^ 4))
610  FOR I = 0 TO 2 * SC
620 SE = FM - PQ(I)
630  IF SE > = 0 THEN PD(I) =  FN P(SE / SG): GOTO
    660
640 PD(I) = 1 - ( FN P( - SE / SG))
660  NEXT I
700  GOSUB 5000
899  REM  CHANGE FOM OR SIGMA ****
900  INPUT "NEW FOM AND SIGMA (Y/N)? :";G$
910  IF G$ = "N" THEN  GOTO 1000
915  INPUT "NEW PROJECT NAME: ";N$
920  INPUT "NEW FIGURE OF MERIT: ";FM
930  INPUT "NEW SIGMA: ";SG
970  GOTO 610
1000  END
4999  REM  CREATE DATA FILE ****
5000  PRINT D$"OPEN";N$ + "-HIRES"
5010  PRINT D$"WRITE ";N$ + "-HIRES"
5012  PRINT 40
5013  PRINT 40
5016  PRINT 400
5017  PRINT 400
5019 KT = 21
5020  DEF  FN A(X) = (KT - X) * S1
5025  FOR I = 1 TO 40
5030 L3 =  FN A(I)
5040  FOR J = 1 TO 40
5050 L1 =  -  FN A(J)
5055 KK = 1
5060  FOR B = 1 TO N1
5070 L2 = L1 - BX(B):L4 = L3 - BY(B)
5080 LN =  SQR (L2 * L2 + L4 * L4)
5090 M =  INT (LN):DR = LN - M:DP = PD(M + 1) - PD(M
    )
```

```
5100 P0 = PD(M) + DP * DR
5110  IF CE(I,J) < P0 THEN CE(I,J) = P0
5120  NEXT B
5130  IF MN > CE(I,J) THEN MN = CE(I,J)
5140  IF MX < CE(I,J) THEN MX = CE(I,J)
5150  NEXT J
5170  FOR J = 1 TO 40
5260  PRINT  INT (TR * CE(I,J)) / TR
5270  NEXT J
5280  NEXT I
5360  PRINT MN
5370  PRINT MX
5380  PRINT D$"CLOSE";N$ + "-HIRES"
5400  RETURN
9999  PRINT D$"PR#0"
10000  END
```

MAP I PROGRAM LISTING

```
2  TEXT : HOME
5  PRINT "                    MAP I"
10  PRINT : PRINT
15  PRINT "THIS PROGRAM GENERATES A DATA FILE TO"
20  PRINT "BE USED AS INPUT FOR THE TOPOGRAPHIC"
25  PRINT "MAPPING SERIES. THE OUTPUT OF THIS"
30  PRINT "PROGRAM IS A PROBABILITY OF DETECTION"
35  PRINT "PLOT.  THIS PROGRAM MAY BE USED FOR"
40  PRINT "LOCALIZATION WITH SINGLE BUOY CONTACT"
45  PRINT "THE PROGRAM RELIES ON BOTH POSITIVE AND"
50  PRINT "NEGATIVE INFORMATION.  THE FIRST BUOY"
55  PRINT "INPUT IS THE BUOY IN CONTACT."
60  PRINT : PRINT
90  INPUT "HIT RETURN TO CONTINUE";A$
95  HOME
99  REM  DEFINE CONSTANTS
100 C1 = .196854:C2 = .115194
110 C3 = .000344:C4 = .019527
115 C5 = .5
120 PI = 4 *  ATN (1):R2 = 50
140 D$ =  CHR$ (4)
150 MN = 100:MX = 0
160 TR = 1000
199  REM  INPUT VARIABLES
200  INPUT "NAME OF PROJECT: ";N$
210  INPUT "SCALE OF PLOT: ";SC
240  INPUT "FIGURE OF MERIT :";FM
250  INPUT "STANDARD DEVIATION OF ESTIMATE: ";SG
275  INPUT "NUMBER OF BUOYS IN PATTERN :";N1
277  INPUT "NUMBER OF BUOYS INB CONTACT : ";N2
279  IF N2 > N1 GOTO 275
280 S1 = SC / 40:S2 = SC / 2:S3 = 2 * SC
290  IF S3 < R2 THEN S3 = R2
299  REM   DIMENSION ARRAYS ****
300  DIM CE(40,40)
310  DIM PD(S3),PQ(S3),PE(S3),PF(S3)
340  DIM BX(N1): DIM BY(N1)
345  FOR I = 1 TO N2
350  PRINT "INPUT X,Y OF CONTACT BUOY #";I;: INPUT "
     : ";BX(I),BY(I)
355  NEXT
360  IF N2 = N1 THEN  GOTO 450
399  REM  INPUT BUOY POSITIONS
400  FOR I = N2 + 1 TO N1
410  PRINT "INPUT X,Y OF BUOY # ";I;" (NO CONTACT) :
     "
420  INPUT BX(I),BY(I)
430  NEXT I
```

```
450  HOME
460  INPUT "PROP LOSS FILENAME (DEL -PLF): ";B$
470  PRINT D$"OPEN ";B$ + "-PLF"
480  PRINT D$"READ ";B$ + "-PLF"
510  FOR I = 0 TO R2
520  INPUT PQ(I)
540  NEXT I
545  PRINT D$"CLOSE ";B$ + "-PLF"
546  IF S3 <  = 50 THEN 600
550  FOR I = R2 + 1 TO 2 * SC
560 PQ(I) = 99
570  NEXT I
599  REM  CONVERT PROP LOSS CURVE TO PROBABILITY OF
    DETECTION CURVE
600  DEF  FN P(X) = 1 - (1 / (2 * (1 + C1 * X + C2 *
    (X ^ 2) + C3 * (X ^ 3) + C4 * (X ^ 4)) ^ 4))
610  FOR I = 0 TO S3
620 SE = FM - PQ(I)
630  IF SE >  = 0 THEN PD(I) =  FN P(SE / SG): GOTO
    650
640 PD(I) = 1 -  FN P( - SE / SG)
650  NEXT I
660  GOSUB 6000
700  GOSUB 5000
899  REM  CHANGE FOM OR SIGMA ****
900  INPUT "NEW FOM AND SIGMA (Y/N)? :";G$
910  IF G$ = "N" THEN  GOTO 1000
915  INPUT "NEW PROJECT NAME: ";N$
920  INPUT "NEW FIGURE OF MERIT: ";FM
930  INPUT "NEW SIGMA: ";SG
970  GOTO 610
1000  END
4999  REM  CREATE DATA FILE ****
5000  PRINT D$"OPEN";N$ + "-HIRES"
5010  PRINT D$"WRITE ";N$ + "-HIRES"
5012  PRINT 40
5013  PRINT 40
5016  PRINT 400
5017  PRINT 400
5018 KT = 21
5019  DEF  FN A(X) = (KT - X) * S1
5020  FOR I = 1 TO 40
5030 L3 =  FN A(I)
5040  FOR J = 1 TO 40
5050 L1 =  -  FN A(J)
5055 KK = 1
5060  FOR B = 1 TO N1
5070 L2 = L1 - BX(B):L4 = L3 - BY(B)
5080 LN =  SQR (L2 * L2 + L4 * L4)
5090  IF B <  = N2 THEN 5110
```

```
5095 M =  INT (LN + C5)
5100 KK = KK * PF(M): GOTO 5120
5110 M =  INT (LN + C5)
5115 KK = KK * PE(M)
5120  NEXT B
5125  IF MN > KK THEN MN = KK
5127  IF MX < KK THEN MX = KK
5130 CE(I,J) = KK
5150  NEXT J
5170  FOR J = 1 TO 40
5260  PRINT  INT (TR * CE(I,J)) / TR
5270  NEXT J
5280  NEXT I
5360  PRINT MN
5370  PRINT MX
5380  PRINT D$"CLOSE";N$ + "-HIRES"
5400  RETURN
6000 P1 = PD(0):P2 = PD(1)
6010  IF P1 =  > P2 THEN PE(0) = P1:PF(0) = 1 - PD(1
   ): GOTO 6030
6020 PE(0) = P2:PF(0) = 1 - PD(0)
6030  FOR I = 1 TO S3 - 1
6040 P1 = PD(I - 1):P2 = PD(I):P3 = PD(I + 1)
6050  IF P1 =  > P2 AND P1 > P3 THEN PE(I) = P1: GOTO
   6080
6060  IF P2 =  > P1 AND P2 =  > P3 THEN PE(I) = P2: GOTO
   6080
6070 PE(I) = P3
6080  IF P1 <  = P2 AND P1 <  = P3 THEN PF(I) = 1 -
   P1: GOTO 6110
6090  IF P2 <  = P1 AND P2 <  = P3 THEN PF(I) = 1 -
   P2: GOTO 6110
6100 PF(I) = 1 - P3
6110  NEXT
6140  RETURN
9999  PRINT D$"PR#0"
10000  END
```

BLOCK II PROGRAM LINE CHANGES

```
285  INPUT MN
286  INPUT MX

]DEL 170,180

]DEL 835, 1010
```

CONTOUR II PROGRAM LINE CHANGES

```
255  INPUT MN
256  INPUT MX


380  HPLOT 0,0 TO (4.4 * HC - 1),0
390  HPLOT  TO (4.4 * HC - 1),(4 * HR - 1)


510 X0 = 4.4 * J


]DEL 160,170
```

LIST OF REFERENCES

1. NAVAIRPAC 01-75 Series (P3-NATOPS Manual), 1970, Chief of Naval Operations, Washington D.C.

2. Dawson, Hugh C. Jr., and Schrinar, Samuel R. Jr., 1981, "Effect of In-situ Bathythermographs on Sonobuoy Search Patterns Based on ICAPS Historical Data", Naval Postgraduate School, Monterey, California.

3. Urick, R. J., 1975, Principles of Underwater Sound 2nd ed., McGraw-Hill, New York.

4. Hurley, William J., 1980, "An Introduction to the Analysis of Underwater Acoustic Detection", Center for Naval Analysis, Alexandria, Virginia.

5. Naval Weather Service Command, June 1972, ASW Oceanographic Environmental Services, Volume 1, Naval Weather Service Command, Washington, D.C.

6. Abramowitz, Milton and Segun, Irene, 1968, Handbook of Mathematical Functions, Dover Publications, New York, NY.

7. Coppens, A. B., Dahl, H. A., Sanders, J. V., February 1981, "Introduction to the Sonar Equations", Naval Postgraduate School, Monterey, California.

8. Cowell, P. L., 1982, "Algorithm Demonstration Report", Systems Control Technology, Palo Alto, California.

9. Westfall, John, 1980, "Users Guide: Topographic Mapping Programs", Special Delivery Software, Cupertino, Caifornia.

10. Cowell, P. L., 1982, "Final Report, SCT Project 5366", Systems Control Technology, Palo Alto, California.

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